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# Eradicating EUROPEAN PINE SHOOT MOTH in Commercial Nurseries with Methyl Bromide

by V. M. Carolin

and W. K. Coulter

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PACIFIC NORTHWEST
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## SUMMARY

This is the third in a series of reports on experimental fumigation of the European pine shoot moth in residential areas and nurseries. Methods and techniques derived in previous studies on single ornamentals were adapted to fumigation of a commercial nursery. An elongate cubical chamber was built for treatment of trees in rows.

Fumigation of an entire commercial nursery is feasible under conditions existing in the Puget Sound area of Washington during late fall and winter. All treatments in which ground tarps were used under chambers resulted in 100-percent shoot moth control. Two treatments in which wet soil was substituted for the ground tarp failed to give 100-percent control; one of these failures was due to too short an exposure period. Tree damage from fumigation was minor and most apparent on lodgepole pine and western white pine.

U.S. FOREST SERVICE
Research Paper PNW-1

# ERADICATING EUROPEAN PINE SHOOT MOTH IN COMMERCIAL NURSERIES WITH METHYL BROMIDE

By

V. M. Carolin and W. K. Coulter

May 1963

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
Philip A. Briegleb, Director Portland, Oregon

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

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## INTRODUCTION

Infested nursery stock is the principal means by which the European pine shoot moth is spread from place to place. Because of the threat to native pine stands, several of the Western States have established quarantines to restrict entry of pines from infested States, and one has regulated intrastate shipments from areas harboring shoot moth infestations in commercial nurseries and ornamental plantings. Fumigation is the only known means of insuring that trees exposed to infestation are free of the shoot moth and safe to plant in uninfested pine-growing areas.

Methods for fumigating to eradicate the European pine shoot moth from single ornamental pines under outdoor conditions were described in two previous reports. The first[1/] gave the results obtained from various combinations of time, temperature, and gas concentration at different seasons of the year. The second[2/] described the equipment and procedures used and reported the tests on which the fumigation techniques were based. The principal accomplishments were:

1. Inexpensive portable chambers made of light frames and plasticized nylon covers, were developed; these showed only minor gas loss for periods up to 5 hours. Proving satisfactory and regarded as "standard" for outdoor fumigation were two cubical wooden-frame chambers, 5 x 5 x 5 feet and 10 x 10 x 10 feet, and two cylindrical chambers with a wire mesh frame, one 3 feet high (25 cubic feet) and the other 5 feet high (100 cubic feet).

2. A standard application technique was devised, in which gas was heated during introduction by routing it through coils in a bucket of hot water. The gas remained uniformly distributed so that circulating devices were unnecessary. However, in order to obtain precise measurement of the average chamber temperature, circulation of the gas-air mixture was desirable when heaters were used or when solar radiation was directed mainly on the top of the chamber.

3. A method was developed for adjusting treatment period according to chamber temperatures measured at 30-minute intervals, so as

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[1/] Carolin, V. M., Klein, W. H., and Thompson, R. M. Eradicating European pine shoot moth on ornamental pines with methyl bromide. Pac. NW. Forest & Range Expt. Sta. Res. Paper 47, 16 pp., illus. 1962.

[2/] Klein, W. H., and Thompson, R. M. Procedures and equipment for fumigating European pine shoot moth on ornamental pines. Pac. NW. Forest & Range Expt. Sta. Res. Paper 50, 25 pp., illus. 1962.

to obtain 100-percent control with minimum tree damage. Time and temperature were the major factors in gaging the proper treatment. Gas concentration was a relatively minor factor in individual tree fumigation. Gas concentration of 4 or 5 pounds per 1,000 cubic feet was satisfactory.

4. Fumigation during winter resulted in the least tree damage to all pine species at the 100-percent control level. Fumigation at chamber temperatures of 45° to 65° F. during early spring (March) was likewise satisfactory.

These findings were applied and modified as needed in a test during a 2-week period in mid-November 1961 to determine the feasibility of treating all pines in a representative small commercial nursery. To complete the test as soon as possible, a six-man crew was used. The objective was to develop guidelines for use in fumigating pine nursery stock on the site in portable chambers. The primary value would be in application of findings to a coordinated eradication effort by nurserymen and interested agencies. However, the findings will be of use to individual nurserymen who want to fumigate small numbers of trees at the time of sale.

Three typical situations, requiring somewhat different procedures, were encountered:

1. Single trees and small groups of trees rooted in the ground were treated in standard chambers.

2. Trees in containers were grouped in standard chambers and various means used to protect the roots.

3. Trees in rows were treated in an elongate version of the 5- x 5- x 5-foot chamber with and without the conventional ground cloth.

## THE TEST NURSERY

The nursery[3/] covers about 5 acres, has 16 large planting beds, and contains a variety of trees, shrubs, and annuals. At the time of the tests, there were 302 pines ranging in size from 1-foot seedlings to 11-foot saplings. These trees were growing singly and in small groups, rows, and containers. For the most part the pines were intermixed with other coniferous and hardwood trees and shrubs, although sections of individual rows were usually restricted to one species. To systematize group treatments, the location and sizes of the various species of pines were plotted on a sketch.

The shoot moth infestation in the pine was described as "moderate." Evidence of shoot moth damage could be found on all sizes, including 1-foot seedlings. Seven species were fumigated; the number of trees of each species, their size, and growing situation were as follows:

| Pine species | In ground | | In containers | | Total number |
|---|---|---|---|---|---|
| | Number | Height (Feet) | Number | Height (Feet) | |
| Mugho | 69 | 1-5 | 111 | 1-2 | 180 |
| Western white | 9 | 5 | 19 | 2-4 | 28 |
| Austrian | 5 | 3-7 | 13 | 4-8 | 18 |
| Lodgepole | 13 | 6-8 | 5 | 4-9 | 18 |
| Japanese red | 0 | -- | 10 | 5-9 | 10 |
| Scotch | 1 | 11 | 0 | -- | 1 |
| Red (native) | 1 | 3 | 1 | 7 | 2 |
| | 98 | | 159 | | 257 |

[3/] Bonnybrook Nursery, 14319 100th Ave. N.E., Bothell, Wash.

## METHODS

A gas concentration of 4 pounds per 1,000 cubic feet was used throughout the nursery fumigation. Adjustment of treatment period proceeded as follows:

1. The chamber temperature was measured at the time of gas introduction and every 30 minutes thereafter. Average temperatures were determined for each 30-minute period.

2. At the end of each 30-minute period, a table of absolute vapor pressure was consulted and the pounds-per-square-inch (p.s.i.) value recorded as an index number.

3. The values equivalent to chamber temperatures for 30-minute periods were added together as an index of treatment until the accumulated sum indicated that less than 30 minutes of further treatment was required.

4. The number of minutes in the final time period was determined by interpolation from a table of vapor pressure, using the ratio of additional vapor pressure needed over vapor pressure for the last temperature measured.

A table for conveniently locating the vapor pressure corresponding to a given chamber temperature is shown below:[4/]

| Chamber temperature (Degrees F.) | Vapor pressure (P.s.i.) | Chamber temperature (Degrees F.) | Vapor pressure (P.s.i.) |
|---|---|---|---|
| 20-22 | 10 | 62-63 | 23 |
| 23-26 | 11 | 64-65 | 24 |
| 27-30 | 12 | 66-67 | 25 |
| 31-34 | 13 | 68-69 | 26 |
| 35-38 | 14 | 70-71 | 27 |
| 39-41 | 15 | 72-73 | 28 |
| 42-44 | 16 | 74-75 | 29 |
| 45-47 | 17 | 76-77 | 30 |
| 48-50 | 18 | 78-79 | 31 |
| 51-52 | 19 | 80 | 32 |
| 53-55 | 20 | 81-82 | 33 |
| 56-58 | 21 | 83 | 34 |
| 59-61 | 22 | 84-85 | 35 |

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[4/] Based on data from Chemical Safety Data Sheet SD-35, Methyl Bromide. Manufacturing Chemists' Association, Inc., 1625 Eye Street, N.W., Washington 6, D.C.

The sums of vapor pressure x time units designated for use in fumigating mugho, Scotch, Austrian, and native red pines ranged from 115 to 120. The number of units designated for lodgepole, Japanese red, and western white pines ranged from 110 to 114, because these species are quite susceptible to damage. Analysis of data from tests in residential areas, later, showed that there is no need to reduce the total treatment, when chamber temperatures are below 62° F.

The effect of fumigation on shoot moth larvae was determined by clipping all infested tips, opening the buds, and examining larvae under a binocular microscope. Phytotoxic effects of fumigation were determined by monthly examinations of all trees, starting in January and ending in June 1962.

## Single Trees and Small Groups

Three kinds of standard chambers were used. The 5-foot cylindrical chamber was used six times for fumigating single, widely spaced mugho pines, 2 to 5 feet high, and once for a single western white pine with several smaller white pines in containers added to the treatment. The 5- x 5- x 5-foot cubical chamber was used three times for single mugho pines. The 10- x 10- x 10-foot cubical chamber was employed four times, for fumigating a single Scotch pine and groups of 5 lodgepole, 2 Austrian, and 20 trees of miscellaneous species.

Fumigation techniques were uniform except for two treatments of mugho pine. In these the ground tarp was omitted and the wet soil beneath the chamber was used as a gas seal.

## Trees in Containers

Two kinds of chambers were used--the 5-foot cylindrical chamber for seedlings in small containers and the 10- x 10- x 10-foot cubical chamber for saplings in large containers. Seedlings in containers were stacked in rows with spaces between each container for gas circulation. Five lots were fumigated; three of these were mugho pines and two were western white pine. The number of trees in each lot ranged from 1 to 82. Saplings in containers were not stacked because of their weight and the relatively small numbers of trees involved. Three lots were fumigated, with one each of lodgepole, Austrian, and Japanese red pine. The number of trees in each lot ranged from five to eight.

Two methods were explored to prevent root damage by gas penetrating into containers. A water seal was used on some of the mugho pine seedlings in small containers; other mughos and all white pines in cans were wrapped in polyethylene bags up to the base of the tree stem. The water seal was obtained by dipping cans in a wheelbarrow of water and by hosing down somewhat larger clay pots and wooden containers. Large containers with saplings were saturated and then were wrapped with pieces of plasticized nylon identical with the material used for chamber jackets.

Trees in Rows

An elongate cubical chamber, adjustable in height and width from 4 to 6 feet and up to 25 feet in length, was built for these fumigations. In some cases, 5- x 5- x 5-foot cubical chambers lined up in a row would have served the same purpose. However, nearly twice as much wood surface would have been exposed, necessitating coating the boards with plastic paint to avoid sorption of gas.

Six 25-foot rows were treated; five of these were mugho pine and one was lodgepole pine. In four lots, the chamber was sealed at the ground line by digging a shallow trench and burying the bottom edge of the chamber jacket 8 inches in the moist soil; the water in the soil under the chamber served as the gas seal. In two lots, two strips of ground cloths were used. In one of these, the cloths were wrapped around the base of each tree. In the other, the two strips were run up to the tree bases, and the intervening spaces around the tree stems and between the strips were packed with wet soil.

Horizontal circulation of gas in these elongate chambers was compared by using two 8-inch household fans in three of the chambers and no circulating devices in the other three chambers. Variation in chamber temperature was checked with thermometers installed at the middle and both ends of each chamber.

## DISCUSSION

The weather during the fumigation period caused some operational difficulties. Thawing after freezing temperatures on several nights turned the nursery beds into a sea of mud the next day. The foot traffic along one of the rows resulted in many of the small pines being splattered with mud, raising the possibility that mud encrusted on an infested shoot would prevent gas penetration. On other days, rain occurred and continued through the night. To insure that trees would be relatively dry the next day, at the end of the day's work chambers were placed over trees with the chamber jacket rolled up halfway.

Location of the nursery in a hollow, with a screen of tall trees on the south and west sides, restricted the amount of solar radiation available to heat the chambers. As a result, chamber temperatures for 30-minute periods ranged from 30° to 75° F. over the 2-week period. On several days the diurnal range was from 35° to 50°, resulting in lengthy treatment periods, many over 3 hours. However, temperatures were optimum for preventing damage to the trees by the fumigant.

Use of standard chambers was efficient, because of their simple design and the familiarity of the crew with the procedure. Setting up the elongate cubical chambers, however, was at first a slow process, because of limited space between the rows and some hindrance from overhanging hardwood foliage plus the need for the crew to get acquainted with the chambers.

The mechanics of determining the fumigation period by measuring chamber temperatures every 30 minutes and looking up the vapor pressure index in a table required constant checking. As a result, a simplified table, shown earlier in this report, was prepared. The lengthy fumigation periods increased the chances of arithmetic errors. In one of the 28 treatments, a computation error resulted in a treatment period too short to kill all the shoot moth larvae.

## RESULTS

The fumigation test showed that fumigation of an entire commercial nursery is feasible under normal late-fall conditions in the Puget Sound area of Washington. Basic data are shown in tables 1 and 2. Specific findings were as follows:

1. All treatments using standard chambers with ground tarps resulted in 100-percent control. Results were similar both for trees in the ground and trees in containers.

2. Two treatments where wet soil was substituted for the ground tarp showed surviving shoot moth larvae. One used a standard 5- x 5- x 5-foot chamber and the other an elongate cubical chamber. In the former, one larva survived. In the latter, an arithmetic error resulted in a sublethal treatment (106 vp·t units) and seven surviving larvae were found.

3. Tree damage resulting from long treatment periods and relatively low temperatures was minor. Only lodgepole pine and western white pine showed appreciable damage. Some lodgepoles lost the 1960 foliage, with the current growth unharmed, and several western white pines turned red and lost all their foliage. All of these pines survived and produced new growth in spring.

4. Group fumigation of trees had no visible effect on gas concentration. Use of a 4-pound concentration at lower temperatures provides some leeway for increase in gas concentration by additional displacement of air volume by trees, since either 4 or 5 pounds is recommended in Research Paper 47 for temperatures of 52° or below.

5. The need for circulating devices in the elongate cubical chamber was neither proved nor disproved. Small differences in gas concentration occurred, but could have been due to chance.

6. Protection of roots of seedlings in containers was obtained for most species by soaking containers in water. The prompt appearance of damage symptoms on white pine in containers, however, suggested that some root damage had occurred.

## RECOMMENDATIONS

1. The 5-foot cylindrical chamber, the 5- x 5- x 5-foot and 10- x 10- x 10-foot cubical chambers, and the recently devised elongate cubical chamber are adaptable to fumigation of commercial nurseries.

2. Standard procedures developed during fumigation of single trees in residential areas should be followed closely in nursery fumigation. Trees must be relatively dry at the time of fumigation, and foliage free of mud and other debris. Substitution of wet soil for the ground tarp as a gas seal is not recommended.

3. Gaging the treatment period by using vapor pressure values to reflect average chamber temperatures for 30-minute periods is an accurate and useful method. However, care must be taken to avoid arithmetic errors. Records should be kept independently by two observers and compared at intervals during fumigation.

4. To minimize tree damage, fumigation of commercial nurseries in western Washington and Oregon should be done at chamber temperatures between 40° and 65° F. If the local weather permits, late fall and winter are acceptable for fumigation operations.

5. Group fumigation of trees is an efficient and effective approach in nursery treatment. Group fumigation of seedlings in containers soaked in water is a useful and timesaving method. Some damage may occur to white pine, but recovery can be expected.

6. Grouping of trees for fumigation should be done according to resistance of different species to methyl bromide damage. Mugho, Scotch, Austrian, and native red pines can be fumigated over a wide range in chamber temperature. Lodgepole, Japanese red, and western white pines should be fumigated only at temperatures below 60° F.

Table 1.--Summary of fumigation treatments made at Bonnybrook Nursery near Bothell, Wash., in November 1961

| Pine species | Number of trees | Height of trees | Chamber size[1/] | Ground seal |
|---|---|---|---|---|
| | | Feet | Cu. ft. | |
| **STANDARD CHAMBERS--SINGLE TREES AND SMALL GROUPS IN GROUND** | | | | |
| Mugho | 1 | 2 | 125 | Nylon tarp |
| Mugho | 1 | 4 | 100 | " " |
| Mugho | 1 | 2 | 100 | Water |
| Mugho | 1 | 4 | 100 | Nylon tarp |
| Mugho[2/] | 2 | 4 | 125 | Water |
| Mugho | 1 | 4 | 125 | Nylon tarp |
| Mugho | 1 | 2 | 100 | " " |
| Mugho | 1 | 3 | 100 | " " |
| Mugho | 1 | 3 | 100 | " " |
| Lodgepole | 5 | 6-8 | 1,000 | " " |
| Austrian | 2 | 7 | 1,000 | " " |
| Scotch | 1 | 11 | 1,000 | " " |
| Miscellaneous | 20 | 2-8 | 1,000 | " " |
| Western white | 9 | 5 | 100 | " " |
| **STANDARD CHAMBERS--TREES IN CONTAINERS** | | | | |
| Western white | 1 in can | 4 | 100 | Nylon tarp |
| Mugho | 4 in cans | 2 | 100 | Water |
| | 4 in cans | 2 | | Plastic |
| | 4 in pots | 2 | | Water |
| | 4 in tubs | 2 | | " |
| | 4 balled | 2 | | Plastic |
| Mugho | 82 in cans | 2 | 100 | Water |
| Mugho | 4 in cans | 2 | 100 | Plastic |
| | 5 in tubs | 2 | | " |
| Lodgepole[3/] | 2 in cans | 4-7 | 1,000 | " |
| | 3 in tubs | 4-7 | | " |
| | 1 planted | 9 | | Nylon tarp |
| Austrian[3/] | 7 in cans | 4-6 | 1,000 | Plastic |
| | 1 planted | 8 | | Nylon tarp |
| Japanese red | 5 in tubs | 5-9 | 1,000 | Plastic |
| Western white | 18 in cans | 2-4 | 100 | " |

See footnotes at end of table.

Table 1--Summary of fumigation treatments made at Bonnybrook Nursery near Bothell, Wash.,...(continued)

MODIFIED CHAMBERS--ROWS OF TREES IN GROUND

| Pine species | Number of trees | Height of trees | Chamber size[1/] | Ground seal |
|---|---|---|---|---|
| | | Feet | Cu. ft. | |
| Mugho | 13 | 1-2 | 500 | Water |
| Mugho | 13 | 1-2 | 500 | " |
| Mugho | 10 | 1-2 | 500 | Nylon tarp |
| Mugho | 12 | 1-2 | 500 | " " |
| Lodgepole | 7 | 6 | 600 | Water |
| Mugho[2/] | 6 | 5 | 500 | " |

1/ All 100-cubic-foot chambers were cylindrical with wire mesh frames. The 125- and 1,000-cubic-foot chambers were cubical with board frames. The 500- and 600-cubic-foot chambers were elongate cubical, 25 x 4 x 5 feet and 25 x 4 x 6 feet, respectively.

2/ Treatment unit in which surviving shoot moth larvae were found.

3/ For efficiency, trees in containers were placed in chamber set up for single large tree rooted in ground.

Table 2.--Results of fumigation treatments at Bonnybrook Nursery near Bothell, Wash., in November 1961

| Treatment number | Pine species | Number of trees | Methyl bromide treatment | Insects | | Tree damage |
|---|---|---|---|---|---|---|
| | | | | Total | Killed | |
| | | | Vp·t units | Number | Percent | |
| 1 | western white | 1 | 110 | 0 | -- | A few needles burned |
| 2 | mugho | 20 | 116 | 3 | 100 | None |
| 3 | lodgepole | 6 | 110 | 4 | 100 | 1960 foliage burned |
| 4 | Austrian | 8 | 115 | 4 | 100 | Some foliage lost on one tree |
| 5 | Japanese red | 5 | 113 | 0 | -- | Slight discoloration of foliage |
| 6 | mugho | 1 | 116 | 6 | 100 | None |
| 7 | mugho | 1 | 115 | 3 | 100 | None |
| 8 | mugho | 1 | 116 | 2 | 100 | None |
| 9 | mugho | 1 | 115 | 0 | -- | None |
| 10 | mugho | 2 | 116 | 7 | 86 | None |
| 11 | mugho | 1 | 101 | 2 | 100 | None |
| 12 | mugho | 1 | 120 | 1 | 100 | None |
| 13 | mugho | 1 | 116 | 3 | 100 | None |
| 14 | mugho | 1 | 117 | 3 | 100 | None |
| 15 | lodgepole | 5 | 110 | 11 | 100 | 1960 foliage burned |
| 16 | Austrian | 2 | 116 | 6 | 100 | A few needles burned |
| 17 | mugho | 82 | 108 | 1 | 100 | None |
| 18 | mugho | 13 | 117 | 30 | 100 | None |
| 19 | mugho | 13 | 116 | 42 | 100 | None |
| 20 | mugho | 10 | 115 | 11 | 100 | None |
| 21 | mugho | 12 | 116 | 7 | 100 | None |
| 22 | mugho | 9 | 117 | 5 | 100 | None |
| 23 | Scotch | 1 | 115 | 0 | -- | None |
| 24 | lodgepole | 7 | 104 | 84 | 100 | None |
| 25 | mugho | 6 | 106 | 36 | 81 | None |
| 26 | western white | 18 | 111 | 1 | 100 | Several trees scorched |
| 27 | miscellaneous | 20 | 116 | 5 | 100 | Some foliage discolored on Japanese red |
| 28 | western white | 9 | 110 | 0 | -- | Some burning of foliage |

Carolin, V. M., and Coulter, W. K.
1963. Eradicating European pine shoot moth in commercial nurseries with methyl bromide. Pac. NW. Forest & Range Expt. Sta. U.S. Forest Serv. Res. Paper PNW-1, 11 pp.

A small commercial nursery in the Puget Sound area of Washington was fumigated in late fall, using previously developed chambers but testing modifications to improve operational efficiency. Somewhat different procedures were used for single trees and small groups, trees in containers, and trees in rows. Adjustment of treatment period according to chamber temperatures is described in detail.

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# LUMBER YIELD and LOG VALUES of SHASTA RED FIR

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## SUMMARY

The value of lumber produced from each of 362 Shasta red fir logs of southern Oregon was determined through a cooperative study in 1960.

Lumber grade yield from each log provided the basis for calculating the comparative value of each log grade–log diameter class, in accordance with grading and scaling practices used both east and west of the Cascade Range.

The results, which are summarized graphically in figure 1, should be useful to sellers, buyers, and processors of Shasta red fir logs. The effect on log value of (1) log diameter, (2) log grade, as determined by two systems, and (3) log scaling, as applied in two systems, should be useful in predicting the lumber output and value of the species, providing the variability between individual logs is recognized. The variability in log value is indicated by including scatter diagrams with the grade-yield and value curves for lumber.

Despite the variability that occurs between individual logs, the results of this study should provide a measure of the expected value spread between log grades and log diameter classes. Refinements in log grading systems, changes in scaling practices, or changes in utilization standards will alter the comparative values developed in this study. As an initial analysis, however, this study provides a basis to evaluate product-yield data that may be developed in future studies of Shasta red fir. For example, a firm could find it helpful to compare its lumber output from a given mix of log grades and sizes with the yield that would be predicted from results of this study.


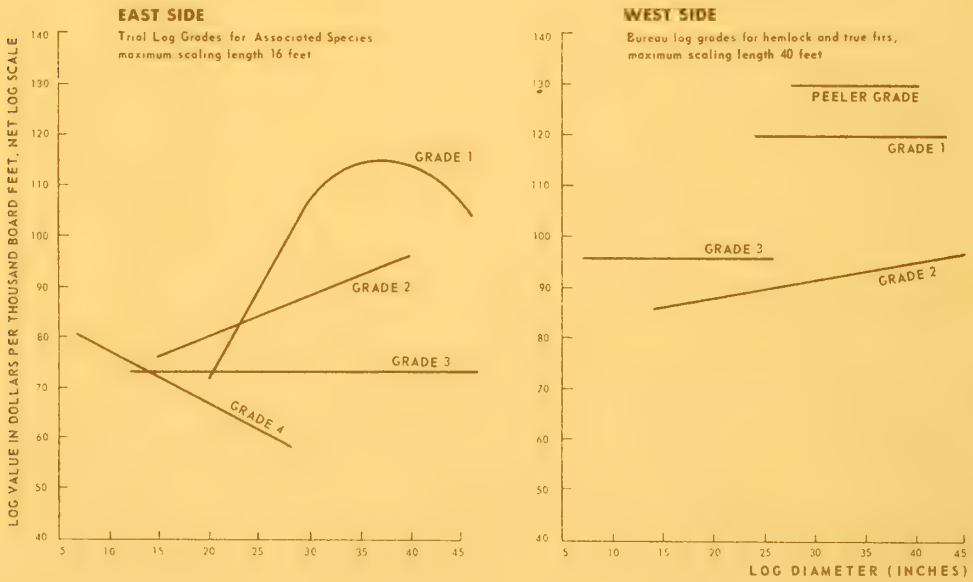
EAST SIDE
Trial Log Grades for Associated Species
maximum scaling length 16 feet
WEST SIDE
Bureau log grades for hemlock and true firs,
maximum scaling length 40 feet
LOG VALUE IN DOLLARS PER THOUSAND BOARD FEET, NET LOG SCALE
GRADE 1
GRADE 2
GRADE 3
GRADE 4
PEELER GRADE
LOG DIAMETER (INCHES)

Figure 1.--Comparative log values for Shasta red fir of southern Oregon when graded and scaled in accordance with east-side and west-side practices.

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## INTRODUCTION

As logging operations have extended into the upper-slope forest types of the southern Cascades and Siskiyou Mountains, interest has increased in the lumber grade yield from the true firs encountered there. As a result, two cooperative studies of lumber grade yield from the true firs of southern Oregon were made in 1960 and 1961. Lumber grade yield from Shasta red fir, studied at Prospect, Oreg., in December 1960,[1/] is reported here and refers to either Shasta red fir or California red fir growing in Oregon.[2/]

Since it is difficult to distinguish Shasta red fir from California red fir, it has been the industry practice to refer to both as Shasta red fir where they occur in Oregon. This report of lumber grade yield from Shasta red fir is applicable to either Shasta or California red fir growing in southern Oregon, since the log sample was drawn from three sale areas on the Rogue River National Forest in Jackson County, Oreg., without distinguishing between the species and its variety.

## PROCEDURE

Logs were accumulated for 3 months to provide a good range of log grade and log diameter classes available in this part of Oregon. Study logs were then selected from the accumulated deck to give two samples: (1) a sample of 362 logs as bucked in the woods and (2) a sample of 671 logs as sawed in the mill after rebucking. As would be expected, the second sample,

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[1/] This study was a cooperative project, with Olson Lawyer Lumber, Inc., U.S. Forest Service, Bureau of Land Management, West Coast Lumber Inspection Bureau, and Bureau of Indian Affairs participating.

[2/] The distribution of Shasta red fir (Abies magnifica var. shastensis) is not clearly distinguished from that of California red fir (Abies magnifica), which it resembles closely. Together they grow in upper-slope stands, generally above the white fir belt, from the Cascade Range of southern Oregon to the Sierra Nevada of central California. Both the type species and the variety resemble noble fir in their size and excellent form but are supposedly distinguished from the latter by bark characteristics at maturity. The bark of mature California red and Shasta red fir is reddish brown to black and deeply furrowed; that of mature noble fir is gray black or purplish and broken into shallow plates that give it a checkered appearance.

which after rebucking included almost twice as many logs, gave the better sample distribution by log grade and diameter class.[3/]

## Sawing Specifications

The logs selected for this study were sawed at the Olson Lawyer Lumber, Inc., mill in Prospect, Oreg.; the lumber output was kiln-dried and surfaced at the company's plant in White City, Oreg. Manufacturing facilities and sawing practices at the band sawmill were considered representative of industry practice for this and related species. Sawing was done to obtain the maximum amount of 5/4-inch Select and Shop lumber and a maximum quantity of Dimension lumber from the lower quality portion of the logs. Only a small proportion of 1-inch Common boards were produced.

The lumber was graded[4/] in both the rough green and surfaced dry condition under the supervision of an inspector from the West Coast Lumber Inspection Bureau.

## Log Diagraming, Grading, and Scaling

In the mill yard the visible surface and end characteristics of each log were recorded on prepared forms so that the relationship of a log's external characteristics to its lumber grade yield could be restudied in detail for purposes of tree grade development or log grade refinement.

Study logs were graded and scaled in accordance with practices in use on both the west side and east side of the Cascade Range. West-side official Bureau log grades[5/] were assigned in the yard by the U.S. Forest Service

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[3/] Since study logs are selected with the objective of providing a representative number of logs in each grade and diameter class, any sample drawn does not represent the log mix available to a given mill. Thus, lumber grade-yield and overrun data, developed in a study, must be weighted by the relative proportions of each log grade and diameter class available to a mill in order to estimate the lumber yield of that mill.

[4/] Grading of Shop lumber, including Molding stock, was in accordance with Standard Grading Rules (1960) of the Western Pine Association, Portland, Oreg.; grading of Selects, Dimension, and Common boards was in accordance with Standard Grading and Dressing Rules, Number 15, for Sitka spruce (revised February 18, 1960) of the West Coast Lumber Inspection Bureau, Portland, Oreg.

[5/] Page 27 of Official Log Scaling and Grading Rules for the Puget Sound, Grays Harbor, Southern Oregon and Northern California Log Scaling and Grading Bureaus. Tacoma, Wash. March 1, 1962.

representative in charge of grading and scaling for the western regions. He also scaled the logs in the yard before bucking (maximum scaling length 40 feet) in accordance with Bureau scaling practices.

Grading by Trial Log Grades for Associated Species (east-side practice)[6/] was done in the mill yard by the same Forest Service representative after logs over 20 feet long were marked for bucking into two pieces. The east-side scale (maximum scaling length 16 feet) was not made, however, until the logs had been bucked on the sawmill deck. This procedure allowed adequate time for careful grading in the yard and still permitted observation of all log ends before they were scaled.

To clarify the application of these procedures, a 22-inch, 36-foot log is used as an example. The log was first graded and scaled in the yard, in accordance with west-side practice, as a grade 2 Sawmill log (Bureau grade) having a gross and net scale of 750 board feet. Next, the log was marked for bucking and graded (in accordance with east-side practice) as a 16-foot grade 2 log (butt) and a 20-foot grade 2 log (top).

When this log entered the sawmill, it was bucked where marked and the sections assigned the next consecutive sawing numbers. Since the maximum scaling length (east-side practice) was 16 feet, the 20-foot top section was scaled as two 10-foot logs. Thus, the gross scale of this log by east-side practice was a combination of two 10-foot logs and a 16-foot butt section which totaled 820 board feet. When the log was bucked on the deck, it appeared sound and both sections were given full scale. In manufacture, the butt section produced 429 board feet of surfaced dry lumber and the top section 487 board feet. Thus, the overruns were 11.7 percent by east-side practice (scaled as three sections) and 22.1 percent by west-side practice (scaled as one log).

The study logs had a net scale of 206,760 and 177,770 board feet when scaled by east-side and west-side practice, respectively. The output of surfaced dry lumber was 232,002 board feet. The east-side scale, made on the sawmill deck after logs were bucked for sawing, gave a total deduction for defect of 24,580 board feet. By comparison, the defect deduction in west-side scaling was 26,020 board feet. Thus, the pronounced difference in net log scale was due almost entirely to the difference in scaling length.

Sawing

Once such pertinent information was recorded for the test logs, they were fed to the saw and cut according to previously agreed-on practice. In

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6/ See page 1 in the appendix.

brief, the company sought the highest value obtainable from each log regardless of the order file, sawing Select and Shop lumber (in 4/4- and 5/4-inch thicknesses) from the outer portion of the log and 2-inch Dimension from the balance.

Each piece of lumber produced from a given log was color coded to maintain its identity until the sawing number of the log could be written on the face of the board. As lumber reached the green sorting chain, each piece was tallied by its rough green dimensions, grade, and log number.

Sawing accuracy at the mill, based on about 150 measurements of each lumber thickness, was generally good. It was best on 2-inch Dimension where more than 90 percent of the pieces measured were 29/16 plus or minus 1/16 inch. More than 85 percent of the 5/4-inch lumber measured 23/16 plus or minus 1/16 inch. One-inch lumber was less uniform in thickness, averaging 18/16 inches but varying plus or minus 2/16 from the average. However, 1-inch lumber represented only 5 percent of the output.

## Kiln-Drying

When sawing was complete, the loads of study lumber were trucked some 40 miles to the company's drying and planing facilities at White City. Company kilns were end-loading, cross-circulating, steam-heated, internal-fan kilns of modern design and in good operating condition. The test lumber, after hand stacking, was dried on the company's usual production schedules. Select and Shop grades were dried to an average moisture content of 8 percent. The company, which produces in an arid part of Oregon and ships a substantial part of its output to arid regions, dried the Dimension test lumber to an average moisture content of 9 percent. A species such as Shasta red fir is expected to tolerate this drying, to a lower than industry average moisture content level, better than a denser species such as Douglas-fir, and there was no evidence of undue degrade in the form of checks, warp, or broken knots.

## Surfacing

Following drying, the lumber was dry-sorted by planing item (dimensions) and by the original green chain grademark. Thus, when one lot of test lumber (such as 2 by 8 Construction) was surfaced, graded, and tallied, the surfaced dry grade yield could be compared with the green grade input. Grading behind the planer was done by certified company graders under the supervision of the same WCLIB inspector who had graded the stock on the green chain.

The surfaced dry lumber output provided the basis for all grade-yield data reported herein, but in order to reveal the surfaced dry yield from an individual log, it was necessary to establish green-to-dry conversion factors. This was done by summarizing the change that occurred in each green grade

for each planing item and computing a weighted-average, surfaced dry output for each green grade input. The rough green grade yield of each individual log was then converted to a surfaced dry yield by means of these conversion factors.

## Analysis of Data

In order to provide for the sale of Shasta red fir timber of southern Oregon, and its subsequent conversion to lumber by either east- or west-side practice, the lumber grade-yield data derived in this study have been analyzed in two ways.

First, lumber grade recovery from the 671 logs sawed was analyzed and summarized. These logs, which varied in length from 12 to 20 feet, were graded in accordance with the Trial Log Grades for Associated Species and scaled in accordance with Forest Service scaling practice then in effect for eastern Oregon—logs over 16 feet in length being scaled as two logs.

Second, the lumber grade yield from the original 362 study logs was obtained by combining the lumber recovery from the two sections of each long log. In this case, each of the 362 logs (ranging from 12 to 40 feet in length) was graded by west-side Bureau grading system and scaled as one log in accordance with Bureau practice for west-side operations.

In analyzing lumber yields and log values for both east- and west-side grading and scaling practices the following procedures were used:

1. Within each log grade (trial grade or Bureau grade) the logs in each 1-inch diameter interval were combined to form a log group. The yield of surfaced dry lumber (by lumber grade) from a log group provided the basic data for computing log values. This information also provided the basis for the lumber grade recovery tables that are included in the appendix.

2. The volume of surfaced dry lumber in each lumber grade was multiplied by the appropriate 1960 price (listed in the appendix) to compute the total value (in dollars) of the lumber yield from each log group.

3. The total value of lumber from each log group was divided by its total volume of surfaced dry lumber to give unit lumber value for the log group. This unit lumber value—expressed in dollars per thousand board feet, lumber tally—is a convenient index of lumber grade yield and is useful in comparing the quality of lumber produced from various grades and/or sizes of logs.

4. The total value of lumber from each log group was divided by its total net log scale to give the unit log value of the group. The unit log value—expressed in dollars per thousand board feet, net log

scale—is the most meaningful value derived, since it reflects not only the quality but the quantity of lumber recovered from a given log group and provides the yardstick for buying and selling timber or logs.

## RESULTS AND DISCUSSION--EAST-SIDE PRACTICE

### Lumber Recovery Based on Trial Log Grades for Associated Species and a 16-Foot Maximum Scaling Length

Distribution of the 671 logs is shown by log grade and diameter class in table 1. The log sample was well distributed by log grade and by diameter classes except for large diameter logs that are always difficult to obtain in the desired number.

The log volume, lumber volume, and lumber value for the logs in each 1-inch diameter interval within each log grade are shown in table 2. This digest of findings not only provides the basis for most subsequent discussion but permits further analysis of results by those who may be interested.

### Lumber Grade Yield by Log Grade-Diameter Class

In order that the influence of log quality and log size on lumber yield may be visualized more readily, the bulk of the study logs has been grouped further into 6-inch diameter intervals. All pertinent data for each of the 6-inch diameter intervals have been summarized in table 3. Any 6-inch diameter interval containing less than 10 logs was omitted from the summary table.

Although much of the variability that occurs in lumber yield is smoothed by grouping logs into 6-inch diameter intervals, such grouping still provides an accurate generalization of lumber grade yield. To illustrate this fact, the yield of each lumber grade from grade 3 logs has been plotted by 1-inch diameter intervals in figure 2. Grade yields for the 6-inch diameter intervals of table 3, if plotted on figure 2, will fit the scatter diagrams rather well.

### Lumber Value as an Index of Lumber Grade Yield

Lumber value, expressed in dollars per thousand board feet, lumber tally, provides a convenient index to lumber grade yield and facilitates comparison of the lumber quality obtained from logs of varying quality and size. Thus, the overall effect of log grade and diameter on lumber grade yield can be judged readily by referring to figure 3.

### Log Value by Log Grade-Diameter Class

Log value, expressed in dollars per thousand board feet, net log scale, is the most meaningful measure of product yield. Since logs generally are purchased on the basis of net log scale, it is important to know the comparative

Table 1.--Distribution of 671 Shasta red fir short logs, by diameter class and log grade, southern Oregon study, 1960

| Diameter class (inches) | Log grades[1/] | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | Total |
| 6- 8 | -- | -- | -- | 10 | 10 |
| 9-11 | -- | -- | -- | 76 | 76 |
| 12-14 | -- | -- | 88 | 11 | 99 |
| 15-17 | -- | 7 | 92 | 10 | 109 |
| 18-20 | 3 | 12 | 81 | 8 | 104 |
| 21-23 | 13 | 20 | 40 | 6 | 79 |
| 24-26 | 12 | 9 | 30 | 2 | 53 |
| 27-29 | 16 | 13 | 18 | 1 | 48 |
| 30-32 | 15 | 8 | 11 | -- | 34 |
| 33-35 | 13 | 4 | 9 | -- | 26 |
| 36-38 | 11 | 4 | 3 | -- | 18 |
| 39-41 | 9 | 1 | -- | -- | 10 |
| 42-44 | 2 | -- | -- | -- | 2 |
| 45-47 | 1 | -- | 1 | -- | 2 |
| 48-50 | -- | -- | 1 | -- | 1 |
| Total | 95 | 78 | 374 | 124 | 671 |

1/ Trial Log Grades for Associated Species.

NOTE: The heavy lines enclose those log grade—diameter classes that are included in table 3. Data from all logs are summarized in tables 8-11 of the appendix.

Table 2.--Net log scale, total lumber volume, and total lumber value for Shasta red fir, by diameter and log grade, southern Oregon study, 1960

| Log diameter (inches) | Log grade[1/] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1 | | | No. 2 | | | No. 3 | | | No. 4 | | |
| | Net log scale | Lumber tally | Lumber value | Net log scale | Lumber tally | Lumber value | Net log scale | Lumber tally | Lumber value | Net log scale | Lumber tally | Lumber value |
| | --- Bd. ft. --- | | Dollars | --- Bd. ft. --- | | Dollars | --- Bd. ft. --- | | Dollars | --- Bd. ft. --- | | Dollars |
| 7 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 90 | 96 | 5.17 |
| 8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 200 | 327 | 17.49 |
| 9 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 780 | 1,097 | 61.40 |
| 10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,530 | 2,146 | 120.68 |
| 11 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2,290 | 2,951 | 166.13 |
| 6-11 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4,890 | 6,617 | 370.87 |
| 12 | -- | -- | -- | -- | -- | -- | 1,960 | 2,802 | 167.57 | 390 | 536 | 28.58 |
| 13 | -- | -- | -- | -- | -- | -- | 3,920 | 4,781 | 275.54 | 290 | 420 | 22.09 |
| 14 | -- | -- | -- | -- | -- | -- | 3,420 | 3,912 | 223.28 | 380 | 575 | 30.77 |
| 15 | -- | -- | -- | 230 | 214 | 13.99 | 4,870 | 5,981 | 348.36 | 360 | 458 | 24.26 |
| 16 | -- | -- | -- | 520 | 516 | 40.43 | 5,130 | 6,571 | 385.93 | 600 | 820 | 45.99 |
| 17 | -- | -- | -- | 270 | 360 | 23.27 | 5,510 | 6,573 | 399.88 | 540 | 510 | 25.94 |
| 12-17 | -- | -- | -- | 1,020 | 1,090 | 77.69 | 24,810 | 30,620 | 1,800.56 | 2,560 | 3,319 | 177.63 |
| 18 | -- | -- | -- | 1,330 | 1,340 | 100.66 | 6,460 | 7,750 | 461.41 | 910 | 1,221 | 67.10 |
| 19 | 210 | 111 | 9.04 | 1,300 | 1,481 | 99.76 | 8,120 | 9,310 | 578.35 | 340 | 354 | 19.54 |
| 20 | 380 | 389 | 24.75 | 280 | 217 | 21.93 | 6,460 | 6,832 | 435.47 | 490 | 523 | 32.89 |
| 21 | 880 | 810 | 79.27 | 4,030 | 4,573 | 335.65 | 4,650 | 5,211 | 329.92 | 820 | 1,017 | 58.45 |
| 22 | 2,030 | 2,001 | 159.01 | 1,730 | 1,682 | 142.81 | 5,380 | 6,173 | 387.49 | 850 | 814 | 47.89 |
| 23 | 1,400 | 1,349 | 124.83 | 830 | 932 | 65.82 | 3,580 | 3,338 | 235.84 | 230 | 285 | 17.46 |
| 18-23 | 4,900 | 4,660 | 396.90 | 9,500 | 10,225 | 766.63 | 34,650 | 38,614 | 2,428.48 | 3,640 | 4,214 | 243.33 |
| 24 | 1,400 | 1,488 | 124.46 | 500 | 560 | 41.70 | 4,150 | 5,246 | 366.27 | 350 | 336 | 17.70 |
| 25 | 870 | 942 | 86.58 | 1,850 | 2,111 | 151.32 | 3,360 | 3,426 | 221.47 | -- | -- | -- |
| 26 | 2,610 | 2,800 | 267.96 | 1,570 | 1,573 | 118.68 | 4,680 | 5,044 | 357.86 | 220 | 246 | 14.30 |
| 27 | 2,690 | 2,901 | 233.06 | 610 | 520 | 49.52 | 3,990 | 4,223 | 282.69 | -- | -- | -- |
| 28 | 4,130 | 4,338 | 430.75 | 5,640 | 6,095 | 493.57 | 3,770 | 3,699 | 281.24 | 540 | 529 | 33.60 |
| 29 | 2,040 | 2,342 | 229.68 | 1,390 | 1,469 | 128.58 | 2,340 | 2,359 | 176.41 | -- | -- | -- |
| 24-29 | 13,740 | 14,811 | 1,372.49 | 11,560 | 12,328 | 983.37 | 22,290 | 23,997 | 1,685.94 | 1,110 | 1,111 | 65.60 |
| 30 | 1,800 | 2,118 | 184.74 | 2,000 | 1,975 | 190.93 | 1,760 | 2,051 | 138.60 | -- | -- | -- |
| 31 | 3,260 | 3,376 | 343.06 | 3,320 | 3,612 | 298.23 | 3,500 | 3,768 | 278.70 | -- | -- | -- |
| 32 | 4,520 | 4,992 | 524.17 | -- | -- | -- | 1,690 | 1,847 | 113.45 | -- | -- | -- |
| 33 | 2,380 | 2,413 | 225.46 | 1,630 | 1,755 | 166.20 | 2,440 | 2,647 | 180.49 | -- | -- | -- |
| 34 | 3,390 | 4,085 | 401.53 | -- | -- | -- | 720 | 733 | 72.06 | -- | -- | -- |
| 35 | 3,690 | 4,117 | 417.95 | 1,620 | 1,821 | 154.90 | 4,130 | 4,658 | 377.91 | -- | -- | -- |
| 30-35 | 19,040 | 21,101 | 2,096.91 | 8,570 | 9,163 | 810.26 | 14,240 | 15,704 | 1,161.21 | -- | -- | -- |
| 36 | 1,570 | 2,221 | 194.41 | -- | -- | -- | 1,740 | 1,809 | 135.12 | -- | -- | -- |
| 37 | 3,510 | 3,876 | 376.81 | 3,270 | 3,297 | 278.32 | 770 | 853 | 53.41 | -- | -- | -- |
| 38 | 3,360 | 3,883 | 403.26 | 890 | 1,015 | 70.34 | -- | -- | -- | -- | -- | -- |
| 39 | 3,390 | 3,852 | 369.04 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 40 | 4,630 | 5,028 | 484.69 | 940 | 1,031 | 85.87 | -- | -- | -- | -- | -- | -- |
| 41 | 760 | 1,090 | 118.99 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 36-41 | 17,220 | 19,950 | 1,947.20 | 5,100 | 5,343 | 434.53 | 2,510 | 2,662 | 188.53 | -- | -- | -- |
| 43 | 2,310 | 2,546 | 269.31 | -- | -- | -- | 760 | 940 | 80.03 | -- | -- | -- |
| 46 | 1,260 | 1,497 | 122.95 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 48 | -- | -- | -- | -- | -- | -- | 1,080 | 1,490 | 76.74 | -- | -- | -- |

[1/] Trial Log Grades for Associated Species.

Table 3.--Log input, lumber yield, and lumber value for Shasta red fir of southern Oregon, based on east-side log grading and scaling practices[1/]

LOG INPUT AND LUMBER YIELD

| Item | Log grade and diameter class | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1 Sawmill | | | | No. 2 Sawmill | | | No. 3 Sawmill | | | | No. 4 Sawmill | | |
| | 18-23 | 24-29 | 30-35 | 36-41 | 18-23 | 24-29 | 30-35 | 12-17 | 18-23 | 24-29 | 30-35 | 6-11 | 12-17 | 18-23 |
| Logs.....number.. | 16 | 28 | 28 | 20 | 32 | 22 | 12 | 180 | 121 | 48 | 20 | 86 | 21 | 14 |
| Gross log scale...board feet.. | 5,630 | 16,070 | 21,970 | 22,020 | 9,790 | 12,950 | 9,580 | 25,540 | 35,750 | 25,580 | 15,760 | 5,060 | 2,650 | 3,840 |
| Net log scale.....board feet.. | 4,900 | 13,740 | 19,040 | 17,220 | 9,500 | 11,560 | 8,570 | 24,810 | 34,650 | 22,290 | 14,240 | 4,890 | 2,560 | 3,640 |
| Defect.....percent.. | 13 | 14 | 13 | 22 | 3 | 11 | 11 | 3 | 3 | 13 | 10 | 3 | 3 | 5 |
| Lumber tally.....board feet.. | 4,659 | 14,812 | 21,100 | 19,951 | 10,225 | 12,328 | 9,163 | 30,619 | 38,613 | 23,996 | 15,704 | 6,617 | 3,320 | 4,214 |
| Overrun.....percent.. | -5 | 8 | 11 | 16 | 8 | 7 | 7 | 23 | 11 | 8 | 10 | 35 | 30 | 16 |
| GRADE YIELD (in percent) | | | | | | | | | | | | | | |
| Dry lumber grades: | | | | | | | | | | | | | | |
| Select: | | | | | | | | | | | | | | |
| C | 10 | 12 | 14 | 14 | 7 | 6 | 12 | 1 | 2 | 3 | 4 | 1 | 0 | 1 |
| D | 6 | 5 | 5 | 5 | 4 | 3 | 3 | 1 | 1 | 3 | 2 | 0 | 0 | 0 |
| Total | 16 | 17 | 19 | 19 | 11 | 9 | 15 | 2 | 3 | 6 | 6 | 1 | 0 | 1 |
| Shop: | | | | | | | | | | | | | | |
| Molding | 20 | 27 | 32 | 29 | 13 | 20 | 23 | 3 | 6 | 12 | 15 | 2 | 1 | 2 |
| All Shop and Outs | 21 | 19 | 20 | 21 | 11 | 21 | 21 | 3 | 13 | 26 | 28 | 2 | 2 | 29 |
| Total | 41 | 46 | 52 | 50 | 24 | 41 | 44 | 6 | 19 | 38 | 43 | 4 | 3 | 31 |
| Common: | | | | | | | | | | | | | | |
| Standard and Better | 14 | 14 | 11 | 13 | 31 | 22 | 17 | 50 | 41 | 24 | 22 | 49 | 46 | 30 |
| Utility | 14 | 11 | 9 | 9 | 19 | 15 | 12 | 25 | 21 | 16 | 15 | 28 | 31 | 21 |
| Economy | 15 | 12 | 9 | 9 | 15 | 13 | 12 | 17 | 16 | 16 | 14 | 18 | 20 | 17 |
| Total | 43 | 37 | 29 | 31 | 65 | 50 | 41 | 92 | 78 | 56 | 51 | 95 | 97 | 68 |
| LUMBER VALUE (in dollars) | | | | | | | | | | | | | | |
| Basis: | | | | | | | | | | | | | | |
| Per M b.m. lumber tally | 85.19 | 92.66 | 99.38 | 97.60 | 74.98 | 79.77 | 83.43 | 58.81 | 62.89 | 70.26 | 73.94 | 56.05 | 53.50 | 57.74 |
| Per M b.m. net log scale | 81.00 | 89.89 | 110.13 | 113.08 | 80.70 | 85.07 | 94.55 | 72.57 | 70.09 | 75.64 | 81.55 | 75.84 | 69.39 | 66.85 |

[1/] Trial Log Grades for Associated Species; maximum scaling length, 16 feet.

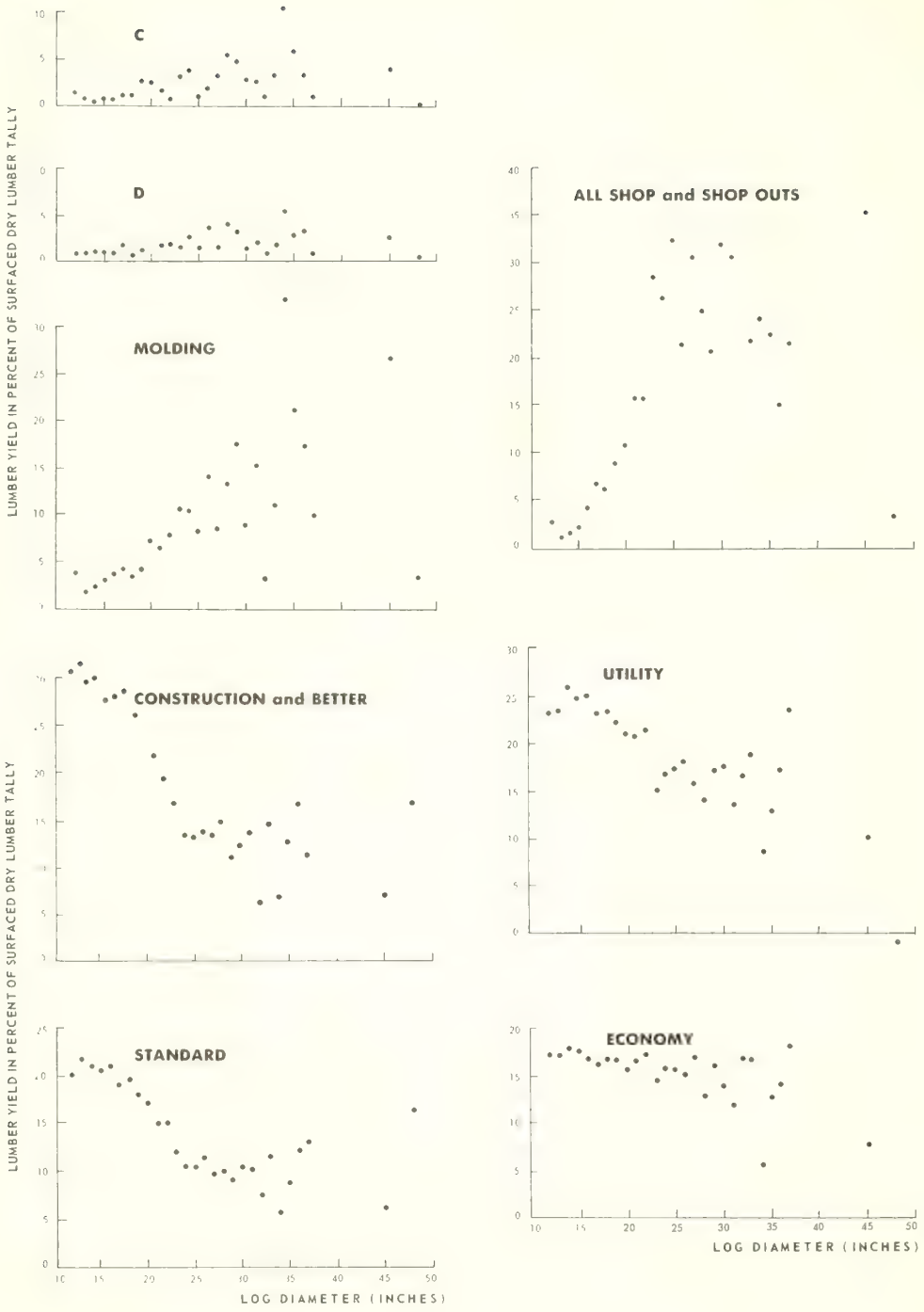


Figure 2.--Lumber grade yield by log diameter for grade 3 logs (Trial Log Grades for Associated Species).

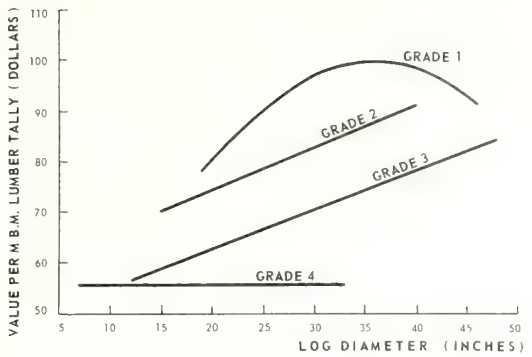


Figure 3.--Relationship of dollars per thousand board feet, dry lumber tally basis, to log diameter by log grade (Trial Log Grades for Associated Species).

value (in dollars per thousand board feet, net log scale) of lumber obtained from logs of varying grade and diameter. The values of Shasta red fir logs are shown separately by 1-inch diameter intervals for each log grade (Trial Log Grades for Associated Species) in figure 4.

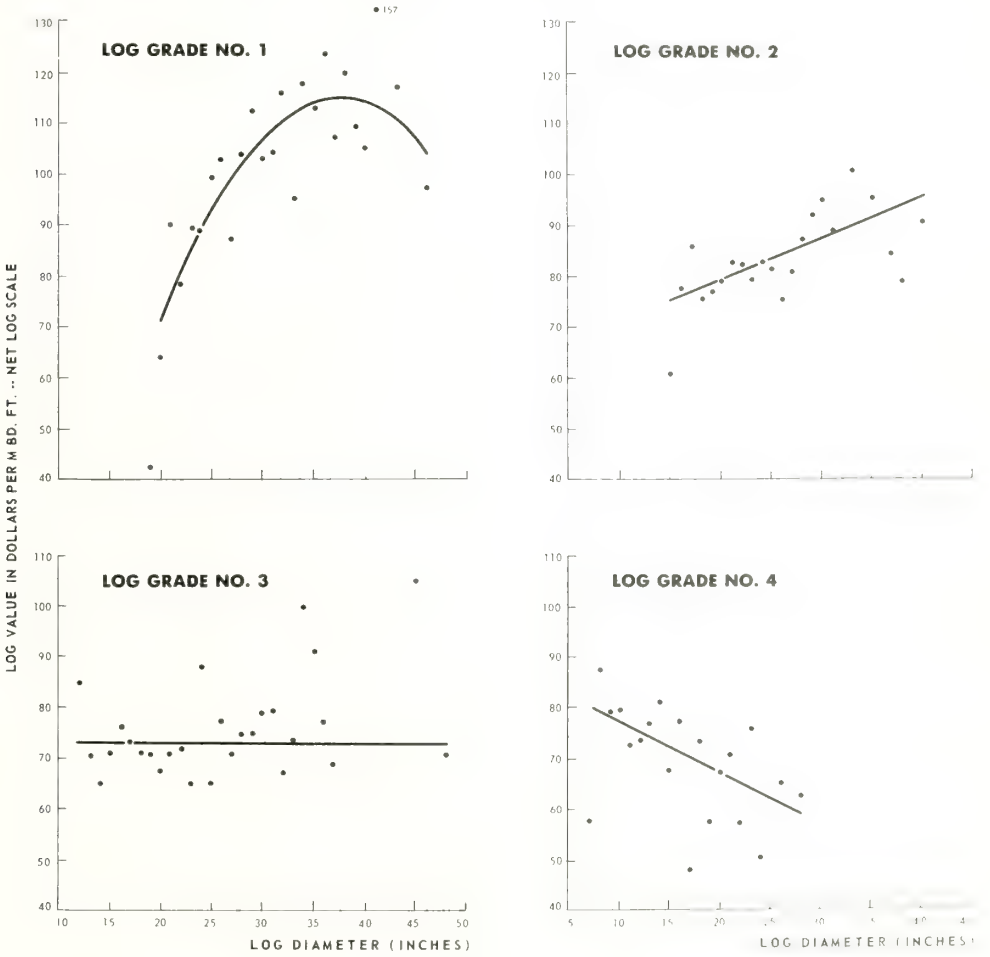


Figure 4.--Relationship of log value (dollars per thousand board feet, net log scale) to diameter by log grade (Trial Log Grades for Associated Species).

Comparison of the curves in figure 4 with those shown in figure 3 reveals that the log value curves generally are higher and of somewhat different slope than the lumber value curves. This is because the log values are influenced by overrun. For example, the lumber value curve for log grade 3 runs from a $57 value for a 12-inch log to an $84 value for a 45-inch log. By comparison, the log value curve for log grade 3 shows a constant value of about $73 for all log diameters--the value differences in table 3 being insignificant. The higher overrun (or greater spread between lumber volume output and net log scale input) developed in small diameter logs has thus offset the somewhat lower value of lumber from small logs.

## Variation in Overrun

Since overrun is automatically considered in determining the log value of each log grade-diameter class, no general overrun curve is included in the report. Trends in overrun by log diameter are evident from the data presented in tables 2 and 3, but considering the variation one should be cautious in generalizing from these data. For example, on first perusal of table 3 the reader may observe a different trend in overrun for each log grade, but this is due in part to the arrangement of the table. If the overruns shown for the 6-inch diameter intervals are arranged for easier comparison, as in table 4, the differences in overrun by log grade are not too marked.

Table 4.--Overrun by log grade and log diameter in percent of dry surfaced lumber

| Log grade | Log diameter class (in inches) | | | | | |
|---|---|---|---|---|---|---|
| | 6-11 | 12-17 | 18-23 | 24-29 | 30-35 | 36-41 |
| 1 | -- | -- | -5 | 8 | 11 | 16 |
| 2 | -- | -- | 8 | 7 | 7 | -- |
| 3 | -- | 23 | 11 | 8 | 10 | -- |
| 4 | 35 | 30 | 16 | -- | -- | -- |

## Relationship of Scaled Defect to Log Diameter

Scaled deductions for defect increased with an increase in log diameter in each log grade as is indicated in table 3. The relationship of scaled defect to log diameter is shown for all log grades combined in figure 5 where defect ranged from 2 percent in the smallest logs to 22 percent in 40-inch logs.

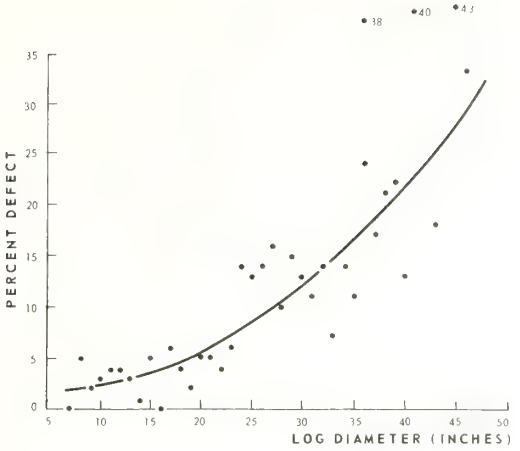


Figure 5.--Relationship of scaled defect percent to log diameter; all log grades combined (Trial Log Grades for Associated Species).

## RESULTS AND DISCUSSION—WEST-SIDE PRACTICE

### Lumber Recovery Based on Bureau Log Grades and a 40-Foot Maximum Scaling Length

Distribution of the 362 logs, as graded and scaled in accordance with west-side practice, is shown in table 5. The log volume, lumber volume, and lumber value of the logs in each 1-inch diameter interval within each log grade are shown in table 6. This digest of study data not only provides the basis for most subsequent discussion but permits a further analysis of results by those who may be interested.

### Lumber Grade Yield by Log Grade-Diameter Class

In order that the influence of log quality and log size on lumber yield may be visualized more readily, the bulk of the logs included in the study has been grouped further into 6-inch diameter intervals. All pertinent log input and lumber output data for each of the 6-inch diameter intervals have been summarized in table 7. Those 6-inch diameter intervals containing less than 10 logs were omitted from the summary table.

Although much of the variability that occurs in lumber yield is smoothed by grouping logs into 6-inch diameter intervals, this grouping still provides an accurate generalization of lumber grade yield. To illustrate this fact, the yield of the common lumber grades from grade 2 logs has been plotted by 1-inch diameter intervals in figure 6. Grade yields for the 6-inch diameter intervals of table 7, if plotted at the midpoint of the diameter class on figure 6, will fit the scatter diagrams rather well.

### Lumber Value as an Index of Lumber Grade Yield

Lumber value (expressed in dollars per thousand board feet, lumber tally) provides a convenient index to lumber grade yield and facilitates

Table 5.--Distribution of 362 Shasta red fir long logs, by diameter class and log grade, southern Oregon study, 1960

| Diameter class (inches) | Log grades[1/] | | | | |
|---|---|---|---|---|---|
| | Peeler | No. 1 | No. 2 | No. 3 | Total |
| 6- 8 | -- | -- | -- | 12 | 12 |
| 9-11 | -- | -- | -- | 52 | 52 |
| 12-14 | -- | -- | 18 | 42 | 60 |
| 15-17 | -- | -- | 50 | 7 | 57 |
| 18-20 | -- | -- | 50 | 9 | 59 |
| 21-23 | -- | -- | 27 | 4 | 31 |
| 24-26 | -- | 7 | 19 | 1 | 27 |
| 27-29 | 2 | 8 | 12 | -- | 22 |
| 30-32 | 3 | 5 | 9 | -- | 17 |
| 33-35 | 1 | 5 | 4 | -- | 10 |
| 36-38 | 1 | 4 | 4 | -- | 9 |
| 39-41 | 2 | 1 | 0 | -- | 3 |
| 42-44 | -- | 1 | 0 | -- | 1 |
| 45-47 | -- | -- | 1 | -- | 1 |
| 48-50 | -- | -- | 1 | -- | 1 |
| Total | 9 | 31 | 195 | 127 | 362 |

[1/] Official Log Scaling and Grading Rules for the Puget Sound, Grays Harbor, Southern Oregon, Northern California, and Tillamook County Log Scaling and Grading Bureaus.

NOTE: The heavy lines enclose those log grade-diameter classes that are included in table 7. Data from all logs are summarized in tables 12-15 of the appendix.

Table 6.--Net log scale, total lumber volume, and total lumber value for Shasta red fir, by diameter and log grade, southern Oregon study, 1960

| Log diameter (inches) | Log grade[1/] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Peeler | | | No. 1 Sawmill | | | No. 2 Sawmill | | | No. 3 Sawmill | | |
| | Net log scale | Lumber tally | Lumber value | Net log scale | Lumber tally | Lumber value | Net log scale | Lumber tally | Lumber value | Net log scale | Lumber tally | Lumber value |
| | --- Bd. ft. --- | | Dollars | --- Bd. ft. --- | | Dollars | --- Bd. ft. --- | | Dollars | --- Bd. ft. --- | | Dollars |
| 7 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 240 | 378 | 19.83 |
| 8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 420 | 818 | 46.25 |
| 9 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,540 | 2,795 | 159.32 |
| 10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,840 | 3,013 | 169.38 |
| 11 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,990 | 3,318 | 188.52 |
| 6-11 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6,030 | 10,322 | 583.30 |
| 12 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2,160 | 3,686 | 212.80 |
| 13 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4,500 | 7,650 | 439.38 |
| 14 | -- | -- | -- | -- | -- | -- | 3,980 | 5,818 | 339.00 | 260 | 534 | 31.58 |
| 15 | -- | -- | -- | -- | -- | -- | 4,560 | 6,292 | 387.81 | 790 | 1,456 | 81.34 |
| 16 | -- | -- | -- | -- | -- | -- | 5,430 | 7,458 | 475.93 | -- | -- | -- |
| 17 | -- | -- | -- | -- | -- | -- | 5,450 | 7,355 | 466.34 | 620 | 839 | 43.16 |
| 12-17 | -- | -- | -- | -- | -- | -- | 19,420 | 26,923 | 1,669.08 | 8,330 | 14,165 | 808.26 |
| 18 | -- | -- | -- | -- | -- | -- | 8,390 | 11,640 | 737.45 | 1,200 | 1,603 | 87.52 |
| 19 | -- | -- | -- | -- | -- | -- | 7,650 | 10,281 | 683.50 | 1,050 | 1,896 | 101.60 |
| 20 | -- | -- | -- | -- | -- | -- | 6,980 | 8,569 | 610.44 | 560 | 698 | 47.27 |
| 21 | -- | -- | -- | -- | -- | -- | 6,560 | 7,761 | 601.91 | 380 | 512 | 32.08 |
| 22 | -- | -- | -- | -- | -- | -- | 6,170 | 7,526 | 523.28 | 940 | 1,355 | 67.57 |
| 23 | -- | -- | -- | -- | -- | -- | 4,370 | 5,313 | 405.42 | 420 | 844 | 57.21 |
| 18-23 | -- | -- | -- | -- | -- | -- | 40,120 | 51,090 | 3,562.00 | 4,550 | 6,908 | 393.25 |
| 24 | -- | -- | -- | 1,480 | 1,784 | 155.03 | 4,490 | 5,595 | 381.17 | -- | -- | -- |
| 25 | -- | -- | -- | 1,660 | 2,231 | 212.67 | 4,110 | 5,408 | 389.99 | -- | -- | -- |
| 26 | -- | -- | -- | 2,330 | 3,033 | 295.19 | 5,460 | 6,606 | 523.45 | 370 | 548 | 32.01 |
| 27 | -- | -- | -- | 4,160 | 4,748 | 400.41 | 3,520 | 3,972 | 278.59 | -- | -- | -- |
| 28 | 1,520 | 1,792 | 194.17 | 3,250 | 4,371 | 432.03 | 5,430 | 6,420 | 481.09 | -- | -- | -- |
| 29 | -- | -- | -- | 1,030 | 1,425 | 137.38 | 2,740 | 3,062 | 222.60 | -- | -- | -- |
| 24-29 | 1,520 | 1,792 | 194.17 | 13,910 | 17,592 | 1,632.71 | 25,750 | 31,063 | 2,276.89 | 370 | 548 | 32.01 |
| 30 | 2,380 | 2,793 | 260.09 | 2,820 | 3,275 | 324.89 | 2,050 | 2,619 | 219.65 | -- | -- | -- |
| 31 | 1,310 | 1,804 | 189.35 | 1,290 | 1,628 | 158.96 | 3,900 | 4,989 | 376.62 | -- | -- | -- |
| 32 | -- | -- | -- | 1,140 | 1,674 | 164.92 | 5,090 | 6,648 | 483.49 | -- | -- | -- |
| 33 | -- | -- | -- | 2,940 | 3,824 | 399.62 | 2,690 | 3,270 | 280.20 | -- | -- | -- |
| 34 | 1,300 | 1,840 | 203.25 | 1,160 | 1,512 | 160.71 | 1,570 | 1,766 | 162.70 | -- | -- | -- |
| 35 | -- | -- | -- | 2,700 | 3,496 | 341.14 | 1,430 | 1,622 | 126.32 | -- | -- | -- |
| 30-35 | 4,990 | 6,437 | 672.69 | 12,050 | 15,409 | 1,550.24 | 16,730 | 20,914 | 1,648.98 | -- | -- | -- |
| 36 | -- | -- | -- | 2,180 | 3,001 | 251.79 | 1,730 | 1,965 | 149.38 | -- | -- | -- |
| 37 | 1,670 | 1,894 | 199.83 | 3,620 | 4,070 | 345.80 | 3,730 | 4,545 | 366.33 | -- | -- | -- |
| 38 | -- | -- | -- | -- | -- | -- | 1,600 | 2,046 | 156.21 | -- | -- | -- |
| 39 | 1,960 | 2,315 | 245.74 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 40 | 2,240 | 2,730 | 294.95 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 41 | -- | -- | -- | 850 | 1,090 | 118.99 | -- | -- | -- | -- | -- | -- |
| 43 | -- | -- | -- | 1,220 | 1,216 | 124.78 | -- | -- | -- | -- | -- | -- |
| 45 | -- | -- | -- | -- | -- | -- | 1,900 | 2,437 | 202.98 | -- | -- | -- |
| 48 | -- | -- | -- | -- | -- | -- | 1,300 | 1,490 | 76.74 | -- | -- | -- |

1/ Official Log Scaling and Grading Rules for the Puget Sound, Grays Harbor, Southern Oregon, Northern California, and Tillamook County Log Scaling and Grading Bureaus.

Table 7.--Log input, lumber yield, and lumber value for Shasta red fir of southern Oregon, based on west-side log grading and scaling practices[1/]

LOG INPUT AND LUMBER YIELD

| Item | Log grade and diameter class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. 1 Sawmill | | No. 2 Sawmill | | | | No. 3 Sawmill | | |
| | 24-29 | 30-35 | 14-17 | 18-23 | 24-29 | 30-35 | 6-11 | 12-17 | 18-23 |
| Logs.....number.. | 15 | 10 | 68 | 77 | 31 | 13 | 64 | 49 | 13 |
| Gross log scale...board feet.. | 17,070 | 14,980 | 20,040 | 42,790 | 29,910 | 19,550 | 6,300 | 8,820 | 5,080 |
| Net log scale.....board feet.. | 13,910 | 12,050 | 19,420 | 40,120 | 25,750 | 16,730 | 6,030 | 8,330 | 4,550 |
| Defect.....percent.. | 19 | 20 | 3 | 6 | 14 | 14 | 4 | 6 | 10 |
| Lumber tally.....board feet.. | 17,593 | 15,410 | 26,923 | 51,090 | 31,064 | 20,915 | 10,319 | 14,164 | 6,949 |
| Overrun.....percent.. | 26 | 28 | 39 | 27 | 21 | 25 | 71 | 70 | 53 |
| **GRADE YIELD (in percent)** | | | | | | | | | |
| Dry lumber grades: | | | | | | | | | |
| Select: | | | | | | | | | |
| C | 11 | 17 | 2 | 4 | 4 | 7 | 1 | 1 | 1 |
| D | 5 | 4 | 1 | 2 | 3 | 3 | 0 | 1 | 1 |
| Total | 16 | 21 | 3 | 6 | 7 | 10 | 1 | 2 | 2 |
| Shop: | | | | | | | | | |
| Molding | 28 | 30 | 5 | 11 | 14 | 18 | 2 | 3 | 3 |
| All Shop and Outs | 21 | 20 | 6 | 15 | 26 | 23 | 1 | 4 | 20 |
| Total | 49 | 50 | 11 | 26 | 40 | 41 | 3 | 7 | 23 |
| Common: | | | | | | | | | |
| Standard and Better | 15 | 11 | 46 | 33 | 22 | 20 | 51 | 46 | 29 |
| Utility | 10 | 9 | 24 | 20 | 16 | 15 | 26 | 26 | 24 |
| Economy | 10 | 9 | 16 | 15 | 15 | 14 | 19 | 19 | 22 |
| Total | 35 | 29 | 86 | 68 | 53 | 49 | 96 | 91 | 75 |
| **LUMBER VALUE (in dollars)** | | | | | | | | | |
| Basis: | | | | | | | | | |
| Per M b.m. lumber tally | 92.80 | 100.60 | 61.99 | 69.72 | 73.30 | 78.84 | 56.52 | 57.06 | 56.60 |
| Per M b.m. net log scale | 116.93 | 128.79 | 86.17 | 88.54 | 88.69 | 98.55 | 96.65 | 97.00 | 86.60 |

[1/] Bureau log grades for hemlock; maximum scaling length, 40 feet.

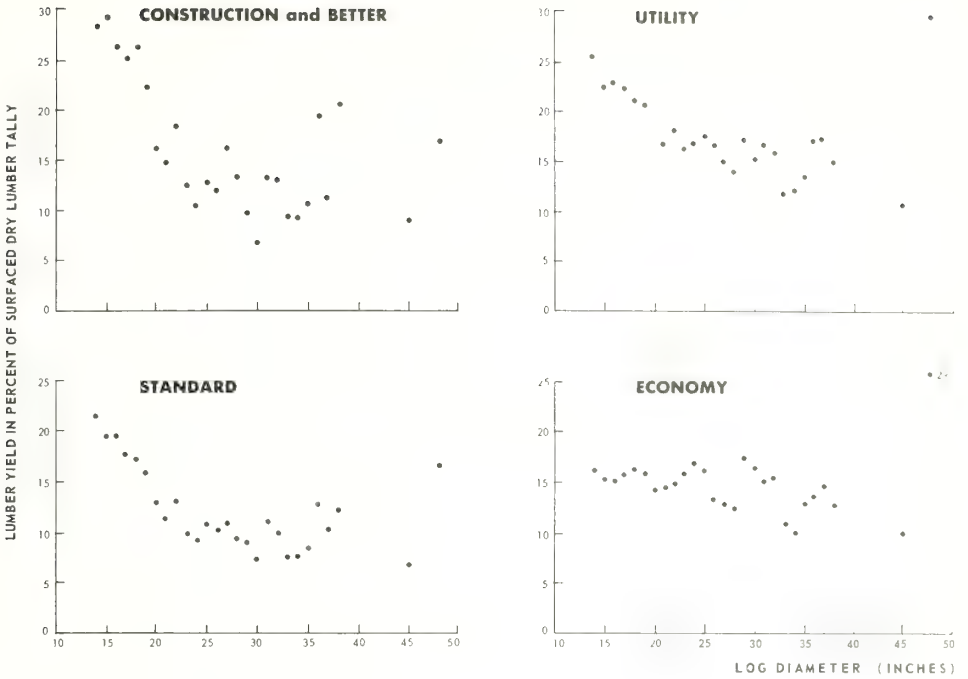


Figure 6.--Common lumber grade yield by log diameter for grade 2 logs (Official Log Scaling and Grading Rules).

comparison of the lumber quality obtained from logs of varying quality and size. Thus, the overall influence of log grade and diameter on lumber grade yield can be judged readily by referring to figure 7.

It is desirable at this point to explain why lumber values plotted over log diameter may give horizontal lines for some log grades, increasing or decreasing straight lines for other log grades, and curved lines for still other log grades. A statistical test of significance was applied to the curved value of each log grade. Only that type of curve that could be statistically defended on the basis of significance was shown. Where the data did not warrant a

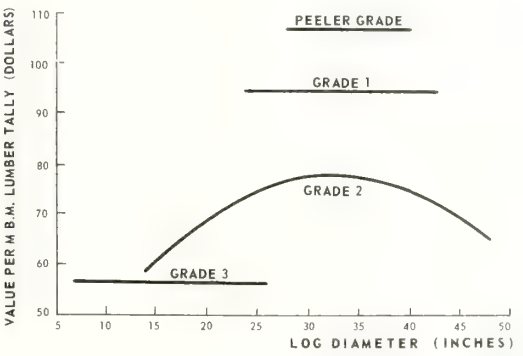


Figure 7.--Relationship of dollars per thousand board feet, dry lumber tally basis, to log diameter by log grade (Official Log Scaling and Grading Rules).

curve (or straight line) of either increasing or decreasing value, the average value for the log grade was shown over all diameters found in the study.

## Log Value by Log Grade-Diameter Class

Log value (expressed in dollars per thousand board feet, net log scale) is the most meaningful measure of product yield. Since logs generally are purchased on the basis of net log scale, it is important to know the comparative value (in dollars per thousand board feet, net log scale) of varying grade and diameter. In figure 8 the values of Shasta red fir logs are shown separately by 1-inch diameter intervals for each log grade (Bureau log grades).

Comparison of the curves in figure 8 with those in figure 7 reveals that the log value curves generally are higher and of somewhat different slope than the lumber value curves. This is because the log values are influenced by overrun. In figure 8 the ratios of dollar value to total net log scale have been plotted for each 1-inch diameter interval to show the variation that exists in a log grade.

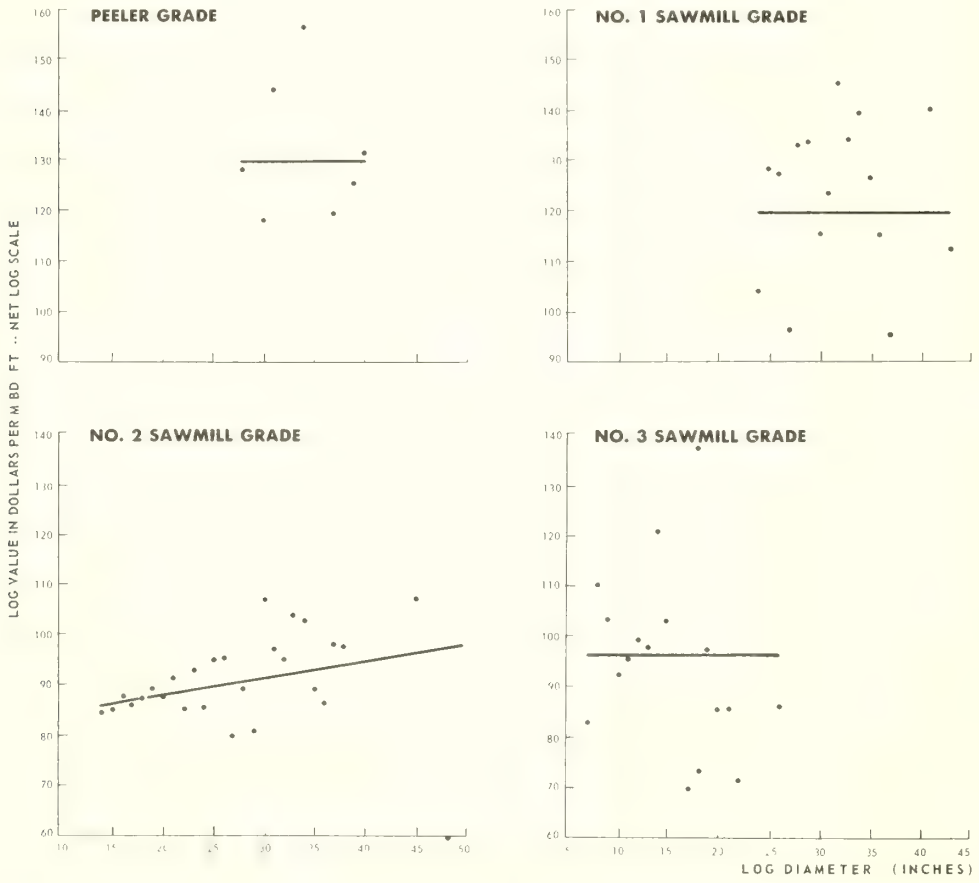
PEELER GRADE
NO. 1 SAWMILL GRADE
NO. 2 SAWMILL GRADE
NO. 3 SAWMILL GRADE
LOG VALUE IN DOLLARS PER M BD FT -- NET LOG SCALE
LOG DIAMETER (INCHES)

Figure 8.--Relationship of log value (dollars per thousand board feet, net log scale) to diameter by log grade (Official Log Scaling and Grading Rules).

## Variation in Overrun

No general overrun is included in this west-side scaling system, since the curves of net log scale include the overrun. The variation in overrun by diameter is evident, however, in the differences between the curves of lumber value and log value. For instance, in the smaller diameters in log grade 2 the increase in value is considerable. An increase of about $26 per thousand board feet is found at the 15-inch diameter class in log grade 2. This increase in value is only $14 at the 30-inch diameter class. Generally speaking, high overrun is associated with small diameters; low overrun, or no overrun, with large diameters.

Overrun also may be influenced by the amount of scaled defect in logs, if some of the scaled defect is included in the lumber output. In this case the average lumber value is decreased, but the overrun is increased. If, on the other hand, the lumber output does not include scaled defect from the log, the average lumber value should be higher but the overrun should be lower. Because log value, per thousand board feet, net log scale, considers both average lumber value and overrun, the end result should be about the same in either case.

## Relationship of Scaled Defect to Log Diameter

The relationship of defect to log diameter, for all log grades combined, is shown in figure 9. The percent of scaled defect increases with increasing diameters up to about 42 inches; there it levels off and begins a downward trend. Plotting the percent of defect over 1-inch diameter intervals shows the variation that exists between log groups. This variation is considerable, even in the smaller diameters where the amount of defect is small. This curved relationship may be used to estimate defect in Shasta red fir logs.

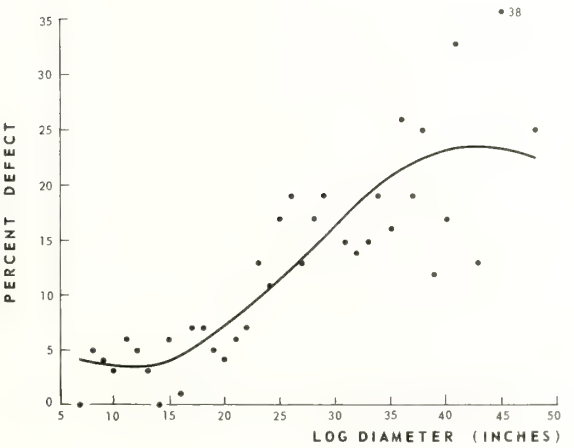


Figure 9.--Relationship of scaled defect percent to log diameter; all log grades combined (Official Log Scaling and Grading Rules).

## Trial Log Grades for Associated Species[7/]

### Grade 1:

Minimum diameter, 18 inches.
Minimum length, 12 feet.
Surface-clear area: 12 feet of length in logs shorter than 16 feet, 75 percent of area in logs 16 feet or longer (three clear faces or 12 feet of clear length).
Exception: Two pin knots allowable on surface-clear portions.
Nonclear faces may have any number of knots of any size.

### Grade 2:

Minimum diameter, 14 inches.
Minimum length, 12 feet.
Surface characteristics:
a. Logs 20 inches or more--
One clear face, and one face with live or dead knots and indicators not over 1 inch in diameter.
b. Logs 17-19 inches--
Two clear faces with one pin knot allowable on one of the clear faces.
c. Logs 14 to 16 inches--
Three clear faces. No pin knots allowed on clear faces.
Nonclear faces may have any number of knots of any size, except as noted.

### Grade 3:

Minimum diameter, 12 inches.
Minimum length, 12 feet.
Surface characteristics:
Any number small knots allowable, but only one knot larger than one-sixth the log diameter permissible.
When a knot larger than one-sixth the log diameter occurs in a knot cluster, a decision must be made as to whether scale or grade of the log will be affected. For such logs, the following rules will apply--
a. Knot clusters or burls not eliminated in the slab require a scaling deduction and shall not be considered in grading logs of associated species.

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7/ Taken from Log Grade Studies in the Ponderosa Pine Region, State of Oregon, Forest Products Research Center, Corvallis, pages 4 and 5.

b. Knot clusters not large enough to require a scaling deduction shall be treated as though the large knot in the cluster were a single knot--surrounding adventitious limbs or knots shall be disregarded.

Grade 4:

Any saw log that is not grade 1, 2, or 3 is grade 4.

Definitions:

A face is one-quarter the log circumference for full length of the log.
A clear face is one with no knots or knot indicators.
A pin knot is a knot up to 1/2 inch in diameter.

Table 8.--Surfaced dry lumber grade recovery from grade 1 Shasta red fir sawmill logs, by 1-inch diameter intervals, east-side practice, southern Oregon study, 1960[1/]

| Log diameter (inches) | Number of logs | Lumber grade | | | | | | | | | | | | | Total lumber tally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | D | Molding | Factory Select | No. 1 Shop | No. 2 Shop | No. 3 Shop | Select Merchantable | Construction | Standard | Utility | Economy | Shop Outs | |
| | | Percent of total recovery | | | | | | | | | | | | | Bd. ft. |
| 19 | 1 | 7.6 | 4.3 | 25.2 | 0 | 0.6 | 7.0 | 5.1 | 1.3 | 3.7 | 7.4 | 17.1 | 20.2 | 0.5 | 111 |
| 20 | 2 | 1.4 | 4.5 | 5.9 | 0.7 | 1.8 | 8.0 | 12.5 | 5.7 | 7.7 | 10.3 | 20.8 | 18.4 | 2.3 | 389 |
| 21 | 3 | 11.6 | 5.3 | 34.4 | 0 | .9 | 9.8 | 8.7 | 1.3 | 2.9 | 5.0 | 10.7 | 8.0 | 1.4 | 810 |
| 22 | 6 | 9.2 | 4.6 | 17.1 | .2 | 1.1 | 8.6 | 9.0 | 2.2 | 5.2 | 8.8 | 17.1 | 16.5 | .4 | 2,001 |
| 23 | 4 | 13.3 | 7.8 | 22.3 | 1.9 | 3.0 | 8.6 | 6.9 | 1.4 | 3.2 | 5.0 | 11.2 | 13.9 | 1.5 | 1,349 |
| 24 | 4 | 6.7 | 3.9 | 26.0 | 0 | .8 | 8.1 | 6.9 | 3.3 | 6.6 | 8.2 | 13.9 | 14.9 | .7 | 1,488 |
| 25 | 2 | 18.6 | 3.5 | 19.8 | 0 | .5 | 5.0 | 4.0 | 4.6 | 8.4 | 9.8 | 14.5 | 11.0 | .3 | 942 |
| 26 | 6 | 14.7 | 6.0 | 27.5 | .2 | 1.0 | 7.7 | 5.6 | 2.8 | 5.4 | 6.5 | 10.7 | 11.4 | .5 | 2,800 |
| 27 | 5 | 10.6 | 1.9 | 18.3 | .1 | 1.3 | 10.0 | 11.0 | 2.6 | 5.3 | 7.1 | 14.4 | 16.7 | .7 | 2,901 |
| 28 | 7 | 13.1 | 6.1 | 34.0 | 0 | .9 | 9.5 | 7.7 | 1.4 | 3.0 | 4.5 | 9.6 | 9.3 | .9 | 4,338 |
| 29 | 4 | 12.5 | 4.6 | 32.6 | .1 | 1.0 | 10.4 | 9.0 | 3.0 | 5.0 | 5.4 | 8.0 | 7.7 | .7 | 2,342 |
| 30 | 3 | 5.0 | 3.4 | 30.2 | .1 | .9 | 9.7 | 7.8 | 4.4 | 7.9 | 8.4 | 11.6 | 10.0 | .6 | 2,118 |
| 31 | 5 | 11.9 | 6.0 | 34.6 | .9 | 2.6 | 12.7 | 9.4 | 1.2 | 2.5 | 3.7 | 7.3 | 6.3 | .9 | 3,376 |
| 32 | 7 | 19.2 | 5.1 | 33.4 | 0 | .9 | 9.0 | 7.4 | 1.6 | 3.0 | 4.2 | 8.2 | 7.2 | .8 | 4,992 |
| 33 | 3 | 9.9 | 5.9 | 29.3 | .1 | 1.8 | 11.7 | 9.1 | 1.8 | 3.5 | 5.5 | 11.0 | 9.8 | .6 | 2,413 |
| 34 | 5 | 16.1 | 4.2 | 30.3 | .4 | 1.5 | 9.3 | 6.7 | 1.9 | 3.7 | 4.8 | 9.4 | 11.1 | .6 | 4,085 |
| 35 | 5 | 15.1 | 5.1 | 34.5 | .1 | 1.1 | 10.1 | 7.5 | 1.4 | 3.0 | 4.4 | 8.5 | 8.6 | .6 | 4,117 |
| 36 | 3 | 11.2 | 2.8 | 20.8 | .9 | 2.9 | 11.5 | 9.8 | 3.2 | 6.0 | 7.4 | 12.0 | 10.4 | 1.1 | 2,221 |
| 37 | 4 | 14.3 | 3.8 | 27.2 | 1.8 | 3.2 | 11.6 | 9.5 | 1.7 | 3.7 | 5.1 | 8.3 | 8.6 | 1.2 | 3,876 |
| 38 | 4 | 14.5 | 4.6 | 37.8 | .1 | 1.0 | 10.6 | 8.2 | 1.7 | 3.3 | 4.0 | 6.8 | 6.6 | .8 | 3,883 |
| 39 | 4 | 17.7 | 5.6 | 22.0 | .7 | 1.6 | 7.2 | 6.4 | 3.8 | 6.3 | 7.0 | 10.8 | 9.9 | 1.0 | 3,852 |
| 40 | 4 | 14.6 | 5.6 | 28.9 | 0 | .8 | 7.9 | 6.1 | 2.8 | 5.0 | 6.4 | 11.2 | 10.2 | .5 | 5,028 |
| 41 | 1 | 18.1 | 4.2 | 39.9 | .1 | 1.1 | 10.9 | 8.2 | 1.3 | 2.5 | 2.9 | 4.7 | 5.4 | .7 | 1,090 |
| 43 | 2 | 12.7 | 5.1 | 39.6 | .4 | 1.7 | 13.2 | 10.5 | 1.6 | 2.8 | 2.7 | 4.3 | 4.6 | .8 | 2,546 |
| 46 | 1 | 6.0 | 4.2 | 19.4 | .2 | 2.5 | 13.9 | 13.0 | 3.6 | 6.6 | 7.3 | 11.3 | 11.5 | .5 | 1,497 |

1/ Trial Log Grades for Associated Species; maximum scaling length, 16 feet.

Table 9.--Surfaced dry lumber grade recovery from grade 2 Shasta red fir sawmill logs, by 1-inch diameter intervals, east-side practice, southern Oregon study, 1960[1/]

| Log diameter (inches) | Number of logs | Lumber grade | | | | | | | | | | | | | Total lumber tally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | D | Molding | Factory Select | No. 1 Shop | No. 2 Shop | No. 3 Shop | Select Merchantable | Construction | Standard | Utility | Economy | Shop Outs | |
| | | Percent of total recovery | | | | | | | | | | | | | Bd. ft. |
| 15 | 2 | 0.5 | 1.2 | 13.7 | 0 | 0.4 | 4.1 | 3.1 | 6.4 | 12.7 | 16.1 | 24.3 | 17.2 | 0.3 | 214 |
| 16 | 3 | 8.4 | 2.5 | 13.6 | 0.3 | 2.2 | 9.4 | 7.6 | 5.4 | 9.5 | 11.9 | 17.7 | 11.1 | .4 | 516 |
| 17 | 2 | .9 | 3.0 | 11.1 | .7 | 1.6 | 6.2 | 9.6 | 3.8 | 6.7 | 10.9 | 24.4 | 18.0 | 3.1 | 360 |
| 18 | 6 | 6.8 | 4.8 | 14.8 | .2 | .7 | 4.4 | 3.7 | 4.7 | 9.1 | 12.8 | 20.9 | 16.5 | .6 | 1,340 |
| 19 | 5 | 3.1 | 1.7 | 11.5 | 0 | .5 | 4.9 | 6.4 | 6.3 | 12.0 | 14.9 | 21.8 | 15.9 | 1.0 | 1,481 |
| 20 | 1 | 28.3 | 5.9 | 15.3 | 0 | .3 | 2.2 | 1.4 | 6.4 | 9.5 | 9.9 | 12.0 | 8.8 | 0 | 217 |
| 21 | 13 | 5.8 | 3.3 | 12.6 | .2 | .7 | 5.2 | 5.6 | 7.2 | 12.1 | 13.6 | 19.2 | 13.9 | .6 | 4,573 |
| 22 | 5 | 13.8 | 4.6 | 16.5 | 0 | .5 | 4.4 | 3.6 | 6.0 | 10.0 | 11.2 | 16.2 | 13.0 | .2 | 1,682 |
| 23 | 2 | 3.6 | 6.7 | 12.9 | 0 | .4 | 4.0 | 3.1 | 5.3 | 10.0 | 12.4 | 22.2 | 19.2 | .2 | 932 |
| 24 | 1 | 3.5 | 4.1 | 15.0 | .1 | 1.5 | 9.0 | 10.5 | 6.2 | 9.5 | 10.4 | 15.7 | 12.9 | 1.6 | 360 |
| 25 | 5 | 1.7 | 1.9 | 17.0 | .4 | 1.8 | 10.7 | 13.1 | 3.3 | 7.1 | 9.8 | 15.9 | 15.2 | 2.1 | 2,111 |
| 26 | 3 | 3.1 | 1.8 | 18.6 | .1 | 1.9 | 11.0 | 10.7 | 3.9 | 8.0 | 11.1 | 16.6 | 12.2 | 1.0 | 1,373 |
| 27 | 1 | 15.9 | 6.9 | 23.2 | 0 | .6 | 5.6 | 3.8 | 5.3 | 9.2 | 8.7 | 10.8 | 9.7 | .3 | 520 |
| 28 | 10 | 6.7 | 3.9 | 21.1 | .1 | 1.0 | 8.4 | 8.1 | 4.2 | 7.8 | 9.3 | 14.9 | 13.9 | .6 | 6,095 |
| 29 | 2 | 14.1 | 2.2 | 19.6 | .1 | .9 | 8.5 | 9.3 | 4.7 | 8.4 | 8.9 | 11.9 | 10.9 | .5 | 1,469 |
| 30 | 3 | 16.8 | 4.2 | 29.1 | .1 | .9 | 8.4 | 6.8 | 1.8 | 3.5 | 4.6 | 10.2 | 13.1 | .5 | 1,975 |
| 31 | 5 | 7.8 | 2.7 | 21.0 | .1 | 1.6 | 11.3 | 11.3 | 3.6 | 6.6 | 8.0 | 13.1 | 12.2 | .7 | 3,612 |
| 33 | 2 | 18.5 | 3.4 | 20.4 | .1 | 1.8 | 10.4 | 9.8 | 4.0 | 6.8 | 6.3 | 8.7 | 9.3 | .5 | 1,755 |
| 35 | 2 | 8.8 | 3.8 | 23.1 | 0 | .8 | 8.1 | 7.3 | 3.8 | 7.8 | 9.9 | 14.4 | 11.7 | .5 | 1,821 |
| 37 | 3 | 9.1 | 5.3 | 22.3 | .1 | .8 | 7.5 | 6.5 | 3.1 | 9.1 | 9.6 | 14.0 | 12.1 | .5 | 3,297 |
| 38 | 1 | 3.2 | 1.1 | 11.8 | 0 | .8 | 4.7 | 4.0 | 9.7 | 16.8 | 15.4 | 17.4 | 14.6 | .5 | 1,015 |
| 40 | 1 | 7.8 | 2.5 | 21.4 | .1 | 1.2 | 9.6 | 9.6 | 5.4 | 9.3 | 9.1 | 12.5 | 10.7 | .8 | 1,031 |

[1/] Trial log grades for Associated Species; maximum scaling length, 16 feet.

Table 10.--Surfaced dry lumber grade recovery from grade 3 Shasta red fir sawmill logs, by 1-inch diameter intervals, east-side practice, southern Oregon study, 1960[1/]

| Log diameter (inches) | Number of logs | Lumber grade | | | | | | | | | | | | | Total lumber tally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | D | Molding | Factory Select | No. 1 Shop | No. 2 Shop | No. 3 Shop | Select Merchantable | Construction | Standard | Utility | Economy | Shop Outs | |
| | | Percent of total recovery | | | | | | | | | | | | | Bd. ft. |
| 12 | 24 | 1.4 | 0.7 | 3.9 | 0 | 0.2 | 1.4 | 1.1 | 11.0 | 19.6 | 20.0 | 23.3 | 17.3 | 0.1 | 2,802 |
| 13 | 37 | .7 | .7 | 1.8 | 0 | 0 | .4 | .6 | 12.0 | 21.0 | 21.6 | 24.0 | 17.1 | .1 | 4,781 |
| 14 | 27 | .5 | .8 | 2.4 | 0 | .1 | .6 | .8 | 10.3 | 19.2 | 21.1 | 26.1 | 17.9 | .2 | 3,912 |
| 15 | 33 | .9 | .8 | 3.0 | 0 | .1 | 1.1 | 1.1 | 10.5 | 19.2 | 20.5 | 24.9 | 17.8 | .1 | 5,981 |
| 16 | 30 | .7 | .7 | 3.8 | 0 | .2 | 1.7 | 2.1 | 9.5 | 18.0 | 21.1 | 25.1 | 16.9 | .2 | 6,571 |
| 17 | 29 | 1.2 | 1.6 | 4.2 | 0.2 | .4 | 2.4 | 3.2 | 10.1 | 17.7 | 18.9 | 23.2 | 16.4 | .5 | 6,573 |
| 18 | 29 | 1.4 | .5 | 3.5 | .1 | .4 | 2.3 | 2.9 | 10.4 | 18.1 | 19.6 | 23.4 | 16.9 | .5 | 7,750 |
| 19 | 31 | 2.7 | 1.1 | 4.4 | .2 | .7 | 3.3 | 4.2 | 9.6 | 16.3 | 17.9 | 22.3 | 16.8 | .5 | 9,310 |
| 20 | 21 | 2.0 | 1.3 | 7.3 | 0 | .5 | 4.1 | 5.6 | 9.2 | 15.3 | 17.0 | 21.1 | 15.8 | .8 | 6,832 |
| 21 | 15 | 1.7 | 1.6 | 6.5 | .3 | 1.1 | 6.2 | 7.5 | 8.1 | 13.6 | 15.0 | 20.9 | 16.8 | .7 | 5,211 |
| 22 | 16 | .9 | 1.8 | 7.8 | .2 | .9 | 6.3 | 7.9 | 6.7 | 12.6 | 15.1 | 21.6 | 17.6 | .6 | 6,173 |
| 23 | 9 | 3.2 | 1.5 | 10.7 | .2 | 1.9 | 11.6 | 13.8 | 6.0 | 10.9 | 11.9 | 15.2 | 12.2 | .9 | 3,337 |
| 24 | 13 | 3.9 | 2.5 | 10.6 | .2 | 1.8 | 10.7 | 12.6 | 4.6 | 8.8 | 10.6 | 16.8 | 16.0 | .9 | 5,246 |
| 25 | 7 | 1.3 | 1.2 | 8.1 | .2 | 1.5 | 12.5 | 17.2 | 4.7 | 8.5 | 10.5 | 17.6 | 15.9 | .8 | 3,426 |
| 26 | 10 | 2.0 | 3.5 | 14.2 | .1 | 1.6 | 9.4 | 9.3 | 4.7 | 9.1 | 11.5 | 18.4 | 15.4 | .8 | 5,043 |
| 27 | 8 | 3.3 | 1.5 | 8.4 | .2 | 2.2 | 11.5 | 14.8 | 4.7 | 8.8 | 9.7 | 16.0 | 17.1 | 1.8 | 4,223 |
| 28 | 6 | 5.6 | 3.8 | 13.6 | .1 | 1.9 | 10.7 | 11.3 | 5.4 | 9.4 | 10.1 | 14.2 | 13.1 | .8 | 3,699 |
| 29 | 4 | 4.8 | 3.1 | 17.7 | .1 | .9 | 9.1 | 10.0 | 3.8 | 7.2 | 9.1 | 17.3 | 16.4 | .5 | 2,359 |
| 30 | 3 | 3.0 | 1.4 | 8.8 | .1 | 1.7 | 12.8 | 16.6 | 4.2 | 8.1 | 10.7 | 17.7 | 14.2 | .7 | 2,051 |
| 31 | 5 | 2.7 | 1.7 | 15.2 | .2 | 2.7 | 13.5 | 13.1 | 4.6 | 9.0 | 10.4 | 13.9 | 12.1 | .9 | 3,768 |
| 32 | 3 | 1.3 | .7 | 3.1 | .5 | 3.6 | 17.2 | 23.5 | 1.9 | 4.4 | 7.6 | 16.7 | 17.1 | 2.4 | 1,847 |
| 33 | 3 | 3.5 | 1.6 | 11.2 | .1 | 1.3 | 9.2 | 10.6 | 4.9 | 9.6 | 11.7 | 19.1 | 16.8 | .4 | 2,647 |
| 34 | 1 | 10.8 | 5.3 | 33.0 | .1 | 1.5 | 11.9 | 9.9 | 2.3 | 4.6 | 5.7 | 8.5 | 5.7 | .7 | 733 |
| 35 | 5 | 5.9 | 2.8 | 21.1 | .4 | 2.0 | 10.5 | 8.9 | 4.5 | 8.3 | 9.0 | 13.2 | 12.7 | .7 | 4,658 |
| 36 | 2 | 3.3 | 3.3 | 17.5 | .1 | 1.1 | 7.5 | 6.0 | 5.9 | 11.0 | 12.3 | 17.5 | 14.1 | .4 | 1,809 |
| 37 | 1 | 1.1 | .9 | 10.0 | .1 | 1.2 | 7.5 | 10.7 | 3.4 | 8.0 | 13.2 | 23.7 | 18.1 | 2.1 | 852 |
| 45 | 1 | 4.2 | 2.6 | 26.8 | .1 | 1.9 | 14.9 | 16.7 | 2.3 | 4.7 | 6.3 | 10.1 | 7.8 | 1.6 | 940 |
| 48 | 1 | .3 | .4 | 3.5 | 0 | .1 | 1.6 | 1.7 | 5.3 | 11.6 | 16.6 | 29.8 | 29.0 | .1 | 1,490 |

[1/] Trial Log Grades for Associated Species; maximum scaling length, 16 feet.

Table 11.--Surfaced dry lumber grade recovery from grade 4 Shasta red fir sawmill logs, by 1-inch diameter intervals, east-side practice, southern Oregon study, 1960[1/]

| Log diameter (inches) | Number of logs | Lumber grade | | | | | | | | | | | | | Total lumber tally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | D | Molding | Factory Select | No. 1 Shop | No. 2 Shop | No. 3 Shop | Select Merchantable | Construction | Standard | Utility | Economy | Shop Outs | |
| | | Percent of total recovery | | | | | | | | | | | | | Bd. ft. |
| 7 | 3 | 0.3 | 0.2 | 0.7 | 0 | 0 | 0 | 0 | 9.8 | 18.8 | 21.5 | 28.1 | 20.6 | 0 | 96 |
| 8 | 7 | .4 | .2 | .7 | 0 | 0 | 0 | 0 | 9.9 | 18.3 | 20.4 | 29.1 | 21.0 | 0 | 327 |
| 9 | 18 | .4 | .3 | 1.9 | 0 | 0 | 0.4 | 0.3 | 10.2 | 19.1 | 21.9 | 26.8 | 18.7 | 0 | 1,097 |
| 10 | 28 | .4 | .5 | 2.1 | 0 | 0.1 | .6 | .8 | 9.8 | 18.5 | 21.7 | 27.1 | 18.2 | 0.2 | 2,146 |
| 11 | 30 | 1.1 | .4 | 2.5 | 0 | .1 | .8 | .7 | 9.9 | 17.4 | 19.9 | 26.9 | 20.2 | .1 | 2,951 |
| 12 | 5 | .2 | .3 | .6 | 0 | 0 | 0 | 0 | 6.6 | 16.5 | 24.7 | 31.1 | 20.0 | 0 | 537 |
| 13 | 3 | .3 | .2 | .6 | 0 | 0 | 0 | 0 | 8.1 | 16.7 | 21.4 | 30.7 | 22.0 | 0 | 420 |
| 14 | 3 | .3 | .2 | .6 | 0 | 0 | .1 | 1.0 | 8.1 | 17.3 | 23.2 | 27.7 | 21.0 | .5 | 575 |
| 15 | 3 | .3 | .3 | .6 | 0 | 0 | 0 | 0 | 7.1 | 16.1 | 23.1 | 32.6 | 19.9 | 0 | 458 |
| 16 | 4 | .3 | .3 | 1.3 | 0 | .3 | 1.4 | 2.8 | 7.8 | 17.6 | 23.7 | 27.5 | 16.2 | .8 | 821 |
| 17 | 3 | .2 | .2 | .5 | 0 | 0 | .3 | 2.5 | 5.5 | 13.2 | 20.7 | 32.2 | 23.6 | 1.1 | 510 |
| 18 | 5 | .2 | .2 | .5 | 0.1 | 1.0 | 5.9 | 8.8 | 6.3 | 13.5 | 18.1 | 25.7 | 18.9 | .8 | 1,221 |
| 19 | 1 | .2 | .3 | 1.8 | .1 | 1.0 | 6.9 | 14.0 | 3.4 | 9.5 | 16.4 | 24.8 | 18.7 | 2.9 | 354 |
| 20 | 2 | .3 | .6 | 6.6 | .1 | .9 | 9.4 | 19.9 | 5.5 | 11.1 | 13.3 | 16.4 | 11.7 | 4.2 | 523 |
| 21 | 3 | .8 | .6 | 1.0 | 1.1 | 2.8 | 10.0 | 15.8 | 4.5 | 9.0 | 11.7 | 20.1 | 19.6 | 3.0 | 1,017 |
| 22 | 2 | 1.2 | .2 | .8 | .1 | 1.9 | 12.4 | 16.8 | 5.4 | 10.8 | 13.5 | 20.4 | 16.1 | .4 | 814 |
| 23 | 1 | .2 | .1 | .4 | .2 | 2.6 | 16.1 | 29.9 | 5.7 | 9.7 | 9.1 | 11.9 | 8.8 | 5.3 | 285 |
| 24 | 1 | .3 | .2 | .7 | 0 | .1 | 1.3 | 2.1 | 8.8 | 16.3 | 18.5 | 28.8 | 22.8 | .1 | 336 |
| 26 | 1 | .2 | .4 | 3.8 | .1 | 1.3 | 13.0 | 19.2 | 2.2 | 6.6 | 12.6 | 21.7 | 18.4 | .5 | 246 |
| 28 | 1 | .2 | .3 | 3.2 | .3 | 4.2 | 20.2 | 24.9 | 2.0 | 5.5 | 10.1 | 16.8 | 10.7 | 1.6 | 529 |

[1/] Trial Log Grades for Associated Species; maximum scaling length, 16 feet.

Table 12.--Surfaced dry lumber grade recovery from Shasta red fir Peeler logs, by 1-inch diameter intervals, west-side practice, southern Oregon study, 1960[1/]

| Log diameter (inches) | Number of logs | Lumber grade | | | | | | | | | | | | | Total lumber tally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | D | Molding | Factory Select | No. 1 Shop | No. 2 Shop | No. 3 Shop | Select Merchantable | Construction | Standard | Utility | Economy | Shop Outs | |
| | | Percent of total recovery | | | | | | | | | | | | | Bd. ft. |
| 28 | 2 | 13.2 | 6.3 | 42.9 | 0.1 | 1.2 | 12.1 | 9.0 | 0.7 | 1.6 | 2.4 | 4.8 | 4.9 | 0.8 | 1,792 |
| 30 | 2 | 15.9 | 4.6 | 31.9 | 0 | .8 | 8.5 | 6.3 | 2.7 | 5.1 | 6.1 | 9.8 | 7.8 | .5 | 2,793 |
| 31 | 1 | 12.0 | 6.1 | 40.8 | .1 | 1.1 | 11.6 | 8.6 | 1.1 | 2.3 | 3.2 | 6.3 | 6.1 | .7 | 1,804 |
| 34 | 1 | 18.6 | 5.7 | 39.7 | .1 | 1.1 | 10.9 | 8.9 | .7 | 1.5 | 1.9 | 4.3 | 5.6 | 1.0 | 1,840 |
| 37 | 1 | 20.7 | 5.1 | 25.7 | 3.3 | 5.0 | 11.9 | 9.7 | .9 | 1.4 | 1.7 | 4.6 | 7.7 | 2.3 | 1,894 |
| 39 | 1 | 21.8 | 6.4 | 28.8 | 0 | .7 | 7.0 | 5.0 | 3.8 | 6.5 | 6.2 | 7.2 | 6.2 | .4 | 2,315 |
| 40 | 1 | 14.2 | 5.1 | 40.4 | .3 | 1.5 | 12.7 | 10.1 | 2.1 | 3.1 | 2.8 | 3.5 | 3.4 | .8 | 2,730 |

[1/] Bureau log grades for hemlock; maximum scaling length, 40 feet.

Table 13.--Surfaced dry lumber grade recovery from grade 1 Shasta red fir sawmill logs, by 1-inch diameter intervals, west-side practice, southern Oregon study, 1960[1/]

| Log diameter (inches) | Number of logs | Lumber grade | | | | | | | | | | | | | Total lumber tally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | D | Molding | Factory Select | No. 1 Shop | No. 2 Shop | No. 3 Shop | Select Merchantable | Construction | Standard | Utility | Economy | Shop Outs | |
| | | Percent of total recovery | | | | | | | | | | | | | Bd. ft. |
| 24 | 2 | 7.6 | 4.5 | 24.7 | 0.1 | 1.2 | 8.9 | 6.8 | 5.1 | 9.2 | 9.2 | 11.7 | 10.5 | 0.5 | 1,784 |
| 25 | 2 | 15.3 | 4.2 | 27.5 | .1 | 1.1 | 9.0 | 7.7 | 2.2 | 4.4 | 6.1 | 10.9 | 10.7 | .8 | 2,231 |
| 26 | 3 | 12.2 | 4.6 | 32.5 | .1 | 1.2 | 10.8 | 9.2 | 2.2 | 4.4 | 5.3 | 8.2 | 8.5 | .8 | 3,033 |
| 27 | 4 | 8.9 | 4.8 | 19.3 | .8 | 2.1 | 10.1 | 9.6 | 3.5 | 6.5 | 8.1 | 13.4 | 12.1 | .8 | 4,748 |
| 28 | 3 | 13.1 | 4.3 | 33.0 | .1 | 1.1 | 10.5 | 8.8 | 2.6 | 4.9 | 5.4 | 8.0 | 7.6 | .6 | 4,371 |
| 29 | 1 | 9.7 | 4.5 | 35.2 | .1 | 1.1 | 11.6 | 9.8 | 1.9 | 3.5 | 4.2 | 8.4 | 9.3 | .7 | 1,425 |
| 30 | 3 | 17.0 | 4.3 | 31.4 | 0 | .9 | 8.9 | 7.7 | 1.4 | 2.8 | 4.1 | 9.3 | 11.3 | .9 | 3,275 |
| 31 | 1 | 7.8 | 4.1 | 37.7 | .1 | 1.4 | 13.0 | 10.8 | 2.2 | 4.0 | 4.4 | 6.7 | 7.0 | .8 | 1,628 |
| 32 | 1 | 18.2 | 5.8 | 26.0 | 0 | .7 | 6.4 | 4.6 | 3.8 | 6.6 | 7.1 | 10.9 | 9.5 | .4 | 1,674 |
| 33 | 2 | 18.4 | 5.3 | 30.9 | .1 | 1.9 | 12.1 | 9.7 | 1.9 | 3.2 | 3.8 | 6.5 | 5.6 | .6 | 3,824 |
| 34 | 1 | 19.8 | 5.3 | 32.5 | 1.3 | 2.4 | 10.5 | 8.1 | .3 | 1.0 | 2.5 | 7.1 | 8.0 | 1.2 | 1,512 |
| 35 | 2 | 17.9 | 3.6 | 27.1 | .1 | 1.1 | 8.2 | 6.3 | 2.9 | 5.5 | 6.6 | 10.5 | 9.7 | .5 | 3,496 |
| 36 | 2 | 10.3 | 3.3 | 17.7 | 1.6 | 3.4 | 10.5 | 8.3 | 3.1 | 5.6 | 7.5 | 14.1 | 13.5 | 1.1 | 3,001 |
| 37 | 2 | 6.8 | 3.8 | 25.7 | .1 | .9 | 9.8 | 9.5 | 3.1 | 6.4 | 8.3 | 13.1 | 11.8 | .7 | 4,070 |
| 41 | 1 | 18.1 | 4.2 | 39.9 | .1 | 1.1 | 10.9 | 8.2 | 1.3 | 2.5 | 2.9 | 4.7 | 5.4 | .7 | 1,090 |
| 43 | 1 | 15.1 | 6.2 | 32.9 | .1 | 1.3 | 10.4 | 7.9 | 2.7 | 4.7 | 4.5 | 6.8 | 6.8 | .6 | 1,216 |

[1/] Bureau log grades for hemlock; maximum scaling length, 40 feet.

Table 14.--Surfaced dry lumber grade recovery from grade 2 Shasta red fir sawmill logs, by 1-inch diameter intervals, west-side practice, southern Oregon study, 1960[1/]

| Log diameter (inches) | Number of logs | Lumber grade | | | | | | | | | | | | | Total lumber tally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | D | Molding | Factory Select | No. 1 Shop | No. 2 Shop | No. 3 Shop | Select Merchantable | Construction | Standard | Utility | Economy | Shop Outs | |
| | | Percent of total recovery | | | | | | | | | | | | | Bd. ft. |
| 14 | 18 | 0.9 | 0.7 | 2.4 | 0.1 | 0.3 | 1.5 | 2.2 | 9.7 | 18.5 | 21.5 | 25.6 | 16.2 | 0.4 | 5,818 |
| 15 | 17 | 1.2 | 1.2 | 5.0 | 0 | .3 | 2.5 | 2.8 | 10.6 | 18.8 | 19.3 | 22.5 | 15.5 | .3 | 6,292 |
| 16 | 18 | 2.2 | 1.4 | 6.9 | 0 | .4 | 2.7 | 2.5 | 9.2 | 17.0 | 19.4 | 22.7 | 15.4 | .2 | 7,458 |
| 17 | 15 | 2.5 | 2.1 | 5.1 | .4 | .8 | 3.1 | 4.1 | 9.4 | 15.8 | 17.6 | 22.3 | 16.0 | .8 | 7,355 |
| 18 | 21 | 2.7 | 1.3 | 5.8 | .1 | .5 | 3.5 | 4.5 | 10.0 | 16.2 | 17.2 | 21.3 | 16.4 | .5 | 11,640 |
| 19 | 16 | 3.5 | 1.6 | 8.8 | .1 | .7 | 4.8 | 5.3 | 8.3 | 14.0 | 15.8 | 20.7 | 15.9 | .5 | 10,281 |
| 20 | 13 | 4.5 | 2.5 | 11.8 | .2 | 1.1 | 7.9 | 9.8 | 5.5 | 10.6 | 12.8 | 18.2 | 14.1 | 1.0 | 8,569 |
| 21 | 11 | 7.5 | 3.5 | 16.0 | .2 | 1.0 | 6.9 | 7.0 | 5.3 | 9.5 | 11.2 | 16.8 | 14.4 | .7 | 7,761 |
| 22 | 10 | 4.0 | 2.6 | 10.1 | .3 | 1.0 | 7.3 | 9.5 | 6.7 | 11.7 | 13.0 | 18.2 | 14.8 | .8 | 7,526 |
| 23 | 6 | 4.8 | 4.3 | 17.0 | .4 | 1.7 | 8.9 | 8.0 | 4.3 | 8.2 | 9.8 | 16.2 | 15.8 | .6 | 5,313 |
| 24 | 7 | 3.9 | 1.6 | 9.1 | .3 | 2.3 | 12.6 | 15.6 | 3.5 | 7.0 | 9.4 | 16.8 | 16.6 | 1.3 | 5,595 |
| 25 | 5 | 4.4 | 4.1 | 12.8 | .2 | 1.2 | 8.7 | 10.5 | 4.3 | 8.4 | 10.7 | 17.6 | 16.2 | .9 | 5,408 |
| 26 | 7 | 6.9 | 3.7 | 18.1 | .1 | 1.4 | 8.8 | 8.0 | 4.1 | 8.0 | 10.3 | 16.7 | 13.2 | .7 | 6,606 |
| 27 | 4 | 2.9 | 2.1 | 10.5 | .1 | 1.6 | 11.9 | 15.3 | 5.7 | 10.4 | 10.9 | 15.0 | 12.8 | .8 | 3,972 |
| 28 | 5 | 3.1 | 2.1 | 15.8 | .2 | 2.7 | 13.4 | 13.0 | 4.7 | 8.5 | 9.4 | 13.9 | 12.3 | .9 | 6,420 |
| 29 | 3 | 4.2 | 2.0 | 17.0 | .1 | 1.2 | 10.2 | 11.3 | 3.3 | 6.4 | 9.0 | 17.2 | 17.4 | .7 | 3,062 |
| 30 | 2 | 11.8 | 3.7 | 18.6 | .1 | 1.4 | 10.1 | 10.7 | 2.2 | 4.5 | 7.3 | 15.2 | 13.8 | .6 | 2,619 |
| 31 | 3 | 4.1 | 2.6 | 18.8 | .1 | 1.1 | 8.5 | 8.0 | 4.4 | 8.9 | 11.1 | 16.7 | 15.1 | .6 | 4,989 |
| 32 | 4 | 4.9 | 2.2 | 13.7 | .2 | 1.6 | 10.3 | 11.8 | 4.5 | 8.5 | 9.9 | 16.0 | 15.4 | 1.0 | 6,648 |
| 33 | 2 | 8.3 | 3.1 | 23.6 | .1 | 1.8 | 11.8 | 11.0 | 3.1 | 6.1 | 7.5 | 11.9 | 10.9 | .8 | 3,270 |
| 34 | 1 | 11.3 | 5.0 | 27.5 | .1 | 1.0 | 8.6 | 6.7 | 3.1 | 6.1 | 7.7 | 12.3 | 10.1 | .5 | 1,766 |
| 35 | 1 | 5.4 | 2.6 | 15.4 | 1.0 | 3.7 | 14.0 | 11.7 | 3.6 | 7.0 | 8.5 | 13.5 | 13.0 | .6 | 1,622 |
| 36 | 1 | 4.8 | 2.7 | 17.9 | 0 | .7 | 6.0 | 4.7 | 6.8 | 12.4 | 12.9 | 17.2 | 13.6 | .3 | 1,965 |
| 37 | 2 | 8.1 | 3.4 | 20.9 | 0 | .7 | 6.7 | 6.2 | 3.7 | 7.5 | 10.1 | 17.4 | 14.6 | .7 | 4,545 |
| 38 | 1 | 5.5 | 1.8 | 16.7 | .1 | 1.0 | 7.1 | 6.8 | 7.5 | 13.1 | 12.2 | 15.0 | 12.6 | .6 | 2,046 |
| 45 | 1 | 5.3 | 3.6 | 22.2 | .2 | 2.3 | 14.3 | 14.3 | 3.1 | 5.9 | 6.9 | 10.8 | 10.1 | 1.0 | 2,437 |
| 48 | 1 | .3 | .4 | 3.5 | 0 | .1 | 1.6 | 1.7 | 5.3 | 11.6 | 16.6 | 29.8 | 29.0 | .1 | 1,490 |

[1/] Bureau log grades for hemlock; maximum scaling length, 40 feet.

Table 15.--Surfaced dry lumber grade recovery from grade 3 Shasta red fir sawmill logs, by 1-inch diameter intervals, west-side practice, southern Oregon study, 1960[1/]

| Log diameter (inches) | Number of logs | Lumber grade | | | | | | | | | | | | | Total lumber tally |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | D | Molding | Factory Select | No. 1 Shop | No. 2 Shop | No. 3 Shop | Select Merchantable | Construction | Standard | Utility | Economy | Shop Outs | |
| | | Percent of total recovery | | | | | | | | | | | | | Bd. ft. |
| 7 | 4 | 0.3 | 0.2 | 0.6 | 0 | 0 | 0 | 0 | 7.7 | 16.3 | 22.1 | 32.1 | 20.7 | 0 | 376 |
| 8 | 8 | 1.2 | .7 | 1.4 | 0 | 0 | 0.1 | 0 | 12.0 | 20.3 | 19.5 | 25.5 | 19.3 | 0 | 818 |
| 9 | 18 | 1.3 | .4 | 3.0 | 0 | 0.2 | .9 | 0.9 | 9.0 | 17.2 | 20.6 | 26.4 | 20.0 | 0.1 | 2,795 |
| 10 | 17 | .4 | .3 | 1.7 | 0 | .1 | .6 | .8 | 10.8 | 19.8 | 21.6 | 25.7 | 18.1 | .1 | 3,013 |
| 11 | 17 | .5 | .5 | 2.1 | 0 | 0 | .5 | .4 | 11.1 | 19.4 | 21.5 | 26.2 | 17.8 | 0 | 3,318 |
| 12 | 16 | .9 | .9 | 3.3 | 0 | .1 | 1.0 | .8 | 10.1 | 18.3 | 19.8 | 25.8 | 18.9 | .1 | 3,685 |
| 13 | 25 | .8 | .7 | 3.0 | 0 | .2 | 1.3 | 1.6 | 9.8 | 18.1 | 20.2 | 25.2 | 18.8 | .3 | 7,650 |
| 14 | 1 | .3 | .4 | 3.0 | 0.1 | .8 | 2.8 | 2.0 | 7.5 | 17.9 | 25.2 | 25.8 | 14.1 | .1 | 534 |
| 15 | 4 | .3 | .5 | 4.3 | 0 | .3 | 3.5 | 7.3 | 5.6 | 12.2 | 17.1 | 26.3 | 20.9 | 1.7 | 1,456 |
| 17 | 3 | .2 | .2 | .5 | 0 | .5 | 3.6 | 9.2 | 5.1 | 11.0 | 15.9 | 27.7 | 23.6 | 2.5 | 839 |
| 18 | 5 | .5 | .2 | .9 | .2 | 1.1 | 5.5 | 10.3 | 5.5 | 11.9 | 16.2 | 25.0 | 20.6 | 2.1 | 1,603 |
| 19 | 3 | .3 | .7 | 1.4 | .1 | .7 | 4.5 | 6.7 | 5.2 | 11.8 | 17.4 | 27.7 | 22.9 | .6 | 1,896 |
| 20 | 1 | .4 | 1.0 | 11.1 | .1 | 1.9 | 9.7 | 10.4 | 6.2 | 12.9 | 15.7 | 17.7 | 11.7 | 1.2 | 698 |
| 21 | 1 | 1.8 | .3 | 1.0 | .2 | 2.3 | 12.6 | 15.8 | 7.5 | 14.0 | 14.9 | 17.8 | 11.4 | .4 | 512 |
| 22 | 2 | .1 | .1 | .5 | .1 | 1.2 | 10.3 | 17.4 | 2.4 | 5.0 | 8.0 | 22.6 | 30.7 | 1.6 | 1,355 |
| 23 | 1 | 4.2 | 1.2 | 11.6 | 0 | .8 | 5.8 | 7.2 | 2.7 | 6.7 | 11.8 | 24.3 | 22.5 | 1.2 | 884 |
| 26 | 1 | .1 | .1 | .3 | .3 | 3.4 | 17.6 | 31.8 | 2.0 | 4.5 | 6.5 | 12.7 | 14.4 | 6.3 | 548 |

1/ Bureau log grades for hemlock; maximum scaling length, 40 feet.

Table 16.--Surfaced dry lumber prices used in calculating lumber values for Shasta red fir[1/]

| Lumber grades | | Price per M b.m. | |
|---|---|---|---|
| Developed in study | Volumes in board feet | From WPA summary | Used in study |
| 5/4 and Thicker C and Better | -- | $158.63 | $158.63 |
| 5/4 and Thicker D | -- | 133.12 | 133.12 |
| 5/4 and Thicker Molding | -- | 130.00 | 130.00 |
| 5/4 and Thicker Factory Select | -- | 121.42 | 121.42 |
| 5/4 and Thicker No. 1 Shop | -- | 109.77 | 109.77 |
| 5/4 and Thicker No. 2 Shop | -- | 78.88 | 78.88 |
| 5/4 and Thicker No. 3 Shop | -- | 59.00 | 59.00 |
| 5/4 and Thicker Shop Outs | -- | 46.45 | 46.45 |
| 4/4 Select Merchantable | 429 | 87.58 | -- |
| 8/4 Select Merchantable | 6,072 | 67.72 | 69.50[2/] |
| 4/4 Construction | 5,184 | 87.58 | -- |
| 8/4 Construction | 50,787 | 67.72 | -- |
| 4/4 Standard | 2,000 | 60.80 | -- |
| 8/4 Standard | 28,121 | 67.72 | 67.26 |
| 4/4 Utility | 3,149 | 49.03 | -- |
| 8/4 Utility | 29,105 | 45.55 | 45.89 |
| 4/4 Economy | 1,673 | 33.28 | -- |
| 8/4 Economy | 20,097 | 23.27 | 24.04 |

[1/] From Western Pine Association's 1960 price summary for white fir, which includes Shasta red fir.

[2/] Weighted by lumber volumes in study.

Grantham, John B., and Hunt, Douglas L.
1963. Lumber yield and log values of Shasta red fir. Pac. NW. Forest & Range Expt. Sta. U.S. Forest Serv. Res. Paper PNW-2, 30 pp., illus.

Lumber grade yield from representative Shasta red fir of southern Oregon was determined in cooperation with industry and other public agencies. Lumber yields and log values--computed by applying 1960 industry prices to these yields--are tabulated by log diameter and log grade in accordance with grading and scaling practices used both east and west of the Cascade Range. Results of the study indicate relative yields and log values of either Shasta or California red fir growing in southern Oregon.

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# NATURAL REGENERATION of Douglas-fir and Associated Species using modified clear-cutting systems in the Oregon Cascades

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U.S. FOREST SERVICE
Research Paper PNW-3

# NATURAL REGENERATION OF DOUGLAS-FIR AND ASSOCIATED SPECIES USING MODIFIED CLEAR-CUTTING SYSTEMS IN THE OREGON CASCADES

by

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September 1963

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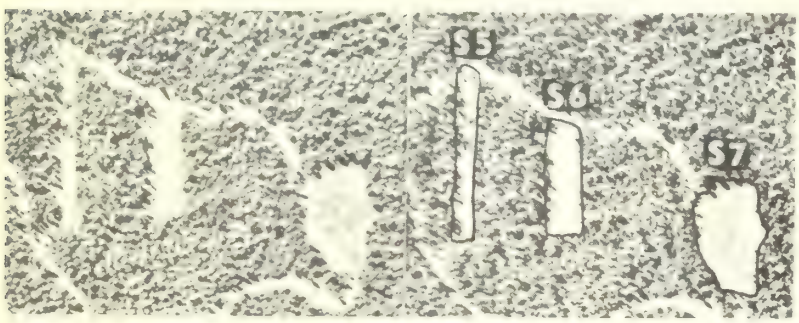
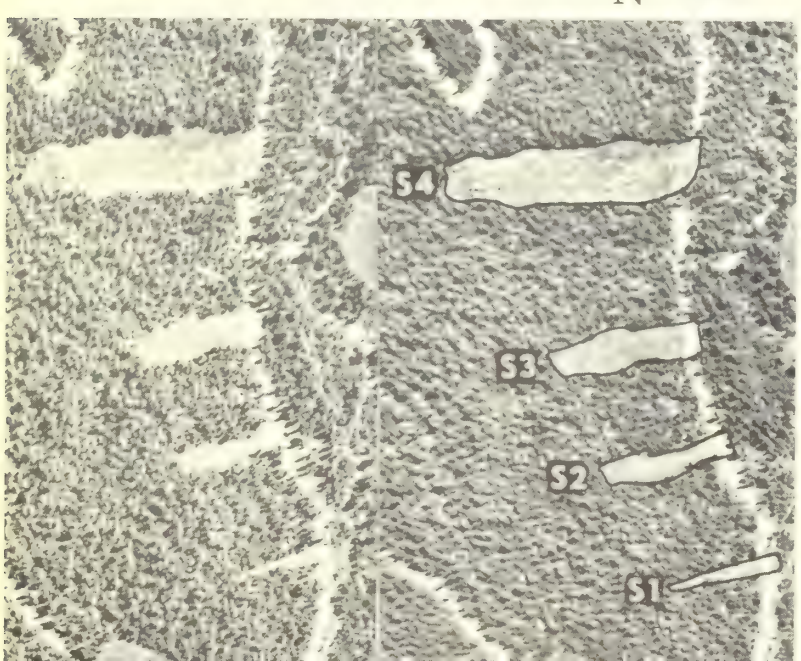
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE




Top: Aerial stereogram of standard clear cut (5B), seed-tree cutting (5C), and patch clear cuts from 1/4 to 4 acres in size (G6 through G1).

Middle: Aerial stereogram of east-west oriented strip clear cuts 100 to 300 feet in width (S5 through S7).

Bottom: Aerial stereogram of north-south oriented strip clear cuts 50 to 350 feet in width (S1 through S4).

## INTRODUCTION

Clear cutting is the standard harvesting system in old-growth Douglas-fir (Pseudotsuga menziesii) forests in the Pacific Northwest. Usually these clear cuts are in "staggered settings" of 15 to 80 acres with the surrounding stand left uncut to provide seed and serve as a firebreak. However, satisfactory natural regeneration of Douglas-fir does not always develop on such cuttings. The erratic and infrequent occurrence of abundant Douglas-fir seed crops and high surface soil temperatures appear to be major deterrents in many areas. Consequently, some modified clear cuts were tried in old-growth Douglas-fir in the western Oregon Cascade Range in 1954 and 1955 to determine their effect on natural regeneration. Cutting was in small patches and in strips of various widths and orientations. One trial of the seed-tree method was included. Cuttings were designed to leave residual trees in patterns that would reduce surface soil temperatures by providing shade and also improve distribution of natural seed fall. Resultant regeneration was examined in the summer of 1959.

## STUDY AREAS

The study areas are located in the H. J. Andrews Experimental Forest on Lookout Creek, a tributary of McKenzie River in the western Oregon Cascades. Timber type before cutting was 400-year-old Douglas-fir with considerable western hemlock (Tsuga heterophylla) and some western redcedar (Thuja plicata). Merchantable timber volumes averaged 50,000 to 100,000 board feet per acre. Precipitation is heavy, in excess of 80 inches annually, and temperatures are mild, averaging 65° F. during the growing season (Berntsen and Rothacher, 1959).

Five general types of cuttings were tried: (1) Clear cutting in strips oriented north and south, (2) clear cutting in strips oriented east and west, (3) clear cutting in small patches ranging from 1/4 acre to 4 acres in size, (4) a seed-tree cutting, and (5) a staggered-setting clear cutting (table 1). Areas were cut and slash burned in 1954 and 1955. Considerable mineral soil seedbed was exposed in all treatments. Surface soils are clay loam in texture on all cuttings. Ground cover at time of the 1959 examination was relatively uniform with no outstanding differences among cutting units.[1/]

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[1/] For a discussion of vegetative composition and coverage on clear cuts in this area, the reader is referred to Yerkes (1960).

Table 1.--Physical and historical data on modified cutting units,

H. J. Andrews Experimental Forest

| Shape and number of unit | Size | Dimensions | | | Average slope | Average elevation | Year | |
|---|---|---|---|---|---|---|---|---|
| | | Width | Length | Radius | | | Logged | Burned |
| | Acres | Feet | | | Percent | Feet | | |
| North-south oriented strip clear cuts: | | | | | | | | |
| S1 | 0.7 | 50 | 600 | -- | 60 | 2,025 | 1954 | 1954 |
| S2 | 1.2 | 100 | 550 | -- | 60 | 2,100 | 1954 | 1954 |
| S3 | 3.6 | 200 | 800 | -- | 50 | 2,125 | 1954 | 1955 |
| S4 | 8.4 | 350 | 1,050 | -- | 40 | 2,175 | 1954 | 1955 |
| East-west oriented strip clear cuts: | | | | | | | | |
| S5 | 2.3 | 100 | 1,000 | -- | 10 | 2,550 | 1954 | 1954 |
| S6 | 3.1 | 200 | 650 | -- | 10 | 2,600 | 1954 | 1954 |
| S7 | 4.0 | 300 | 575 | -- | 20 | 2,650 | 1954 | 1955 |
| Rectangular patch clear cuts: | | | | | | | | |
| G1 | 4.0 | 435 | 400 | -- | 20 | 3,100 | 1955 | 1955 |
| G2 | 2.0 | 250 | 350 | -- | 10 | 3,125 | 1955 | 1955 |
| G3 | 1.0 | 200 | 220 | -- | 0 | 3,075 | 1955 | 1955 |
| Circular patch clear cuts: | | | | | | | | |
| G4 | .75 | -- | -- | 102 | 0 | 3,025 | 1955 | 1955 |
| G5 | .50 | -- | -- | 83 | 10 | 3,025 | 1955 | 1955 |
| G6 | .25 | -- | -- | 49 | 20 | 3,050 | 1955 | 1955 |
| Staggered-setting clear cut: | | | | | | | | |
| 5B | 48.4 | -- | -- | -- | 20 | 3,200 | 1955 | 1955 |
| Seed-tree cutting: | | | | | | | | |
| 5C | 20.4 | -- | -- | -- | 10 | 3,300 | 1955 | 1955 |

Exposure and topography within individual clear cuts are fairly uniform except units S4, 5B, and 5C (table 1), where exposure varies due to presence of minor stream drainages. The north-south strip clear cuts are on a steep, south-facing slope with a relatively shallow soil at an elevation of 1,850 to 2,375 feet. The other cuttings are on a gentle, south-facing slope with deeper soil at elevations ranging from 2,550 to 3,500 feet. Thus, the north-south strip clear cuts occupy a hotter and drier habitat than the other cuttings.

## CONE CROPS

Continuous records of Douglas-fir and western hemlock cone crops have been kept on the experimental forest. During the study period, average ratings[2/] were:

| Years | Douglas-fir | Western hemlock |
|---|---|---|
| 1954 | Medium | Abundant |
| 1955 | Light | Light |
| 1956 | Abundant | Medium |
| 1957 | Failure | Medium |
| 1958 | Failure | Light |

## FIELD MEASUREMENTS

Species, amount, and distribution of natural regeneration were used as the main criteria for comparing the different types of cuttings. Tree seedlings were counted on milacre plots located along transects. Transects (usually 10 per cutting) were surveyed across cuttings with their direction parallel to the narrow side of the cutting. Number of milacre plots varied from 90 to 225 per cutting, depending in part on size and shape of unit.

A Douglas-fir seedling in its second growing season was considered established; two 1-year-old seedlings were considered its equivalent. A western hemlock or western redcedar seedling in its third season was considered established; three seedlings either 1 or 2 years old were considered its equivalent. For strip and patch clear cuts, hours during which the center of the plot received

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[2/] Data based on averages of general observations of number of cones at seven locations. Ratings provide a relative measure only.

shade from adjacent timber between 6 a.m. and 6 p.m. were estimated, using a technique described by Silen.[3/]

## RESULTANT STOCKING

If stocking of any species on 30 percent of the milacre plots is considered adequate, all cuttings except the staggered-setting were adequately stocked with tree seedlings (table 2).[4/] Considering Douglas-fir alone, all cuttings except the staggered-setting and 2-acre patch clear cut were stocked. As groups, the east-west strip clear cuts had the best stocking, north-south strip clear cuts and staggered-setting were poorest, and patch clear cuts and the seed-tree cutting were intermediate.

The staggered-setting clear cut had only 407 Douglas-fir seedlings per acre and 28 percent of the plots stocked with any species.

Poor stocking is typical of many large clear cuts in this general area. For example, twelve 3- to 5-year-old clear cuts on the experimental forest surveyed in 1956 had an average of only 301 (range 81 to 525) Douglas-fir seedlings per acre. Total plots stocked with any species averaged 28 (range 11 to 48) percent and plots stocked with Douglas-fir averaged only 24 (range 9 to 36) percent, even though both 1- and 2-year-old seedlings were included in the tally.

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[3/] Silen, Roy Ragnar. Lethal surface temperatures and their interpretation for Douglas-fir. Unpublished Ph. D. thesis on file Oreg. State Univ. 170 pp., illus. 1960.

This technique involves use of a protractor placed with the index mark at center of plot and oriented with the 90° mark toward south. Protractor is tilted at a 45° angle toward north to aline its surface with celestial equator. Path of the sun for six spring and summer months lies somewhere in a band 23° wide north of celestial equator marked by protractor edge. Stand edge producing shade must lie within the skyward projection of this imaginary band. Since the sun moves along the band at 15° per hour, hours of shade on each plot can be estimated with the protractor in terms of degrees and then converted to hours. A pencil, with the point held at the center of the plot on the protractor index mark, was swung on the sun's apparent path, and the hours the plot was receiving stand shade were estimated. The principles for such approximations are found in any general surveying textbook.

[4/] Thirty percent is the usual 1-milacre stocking criterion used in the Northwest. Percent of milacre plots stocked is not completely satisfactory as a measure of overall adequacy of regeneration on a clear cut, although it is better than number of seedlings per acre. A map showing distribution of stocked plots within a cutting is probably best. In this study, stocked plots were generally well distributed on small cuttings but confined to the outer area of the staggered-setting cutting.

Table 2.--Stocking established seedlings on standard and modified clear cuts, H. J. Andrews Experimental Forest, 1959

| Unit | Kind of cutting unit | Milacre plots | Stocking | | |
|---|---|---|---|---|---|
| | | | Plots stocked, all species | Plots stocked, Douglas-fir | Douglas-fir seedlings per acre |
| | | Number | Percent | Percent | Number |
| S1 | North-south 50-foot strip | 102 | 61 | 57 | 1,466 |
| S2 | North-south 100-foot strip | 118 | 35 | 31 | 597 |
| S3 | North-south 200-foot strip | 96 | 40 | 34 | 573 |
| S4 | North-south 350-foot strip | 141 | 60 | 45 | 908 |
| S5 | East-west 100-foot strip | 90 | 81 | 68 | 1,733 |
| S6 | East-west 200-foot strip | 99 | 89 | 81 | 4,561 |
| S7 | East-west 300-foot strip | 174 | 69 | 59 | 1,899 |
| G1 | 4-acre square patch | 204 | 58 | 42 | 824 |
| G2 | 2-acre square patch | 116 | 60 | 29 | 474 |
| G3 | 1-acre square patch | 102 | 81 | 45 | 814 |
| G4 | 3/4-acre circular patch | 114 | 75 | 58 | 1,658 |
| G5 | 1/2-acre circular patch | 107 | 72 | 64 | 2,276 |
| G6 | 1/4-acre circular patch | 130 | 72 | 44 | 888 |
| 5B | Staggered-setting | 225 | 28 | 21 | 407 |
| 5C | Seed-tree | 125 | 61 | 50 | 1,448 |

The wide variation in level of stocking among units essentially homogeneous in character is noteworthy. For example, the three east-west strip clear cuts occupy similar topography, but percent of plots stocked with Douglas-fir varied from 59 to 81 and number of Douglas-fir seedlings varied from 1,733 to 4,561 per acre.

## REGENERATION AND GROSS CHARACTERISTICS OF CLEAR CUTS

The first analyses were made to determine if stocking levels were related to measurable characteristics of the 13 small clear cuts. Three different measures of stocking were used: (1) percent of plots stocked with all species, (2) percent of plots stocked with Douglas-fir, and (3) number of Douglas-fir seedlings per acre. Characteristics of clear cuts were expressed as: (1) size of clear cut, (2) average hours of shade on clear cut, (3) width of clear cut in narrowest dimension, (4) width of clear cut in north-south dimension, and (5) average distance of plots from stand edge. In the regression analyses, all relationships were tested, using each clear cut as a single observation.

Only one relationship was revealed to be significant[5/]--the relation of percent of milacre plots stocked with any species and the north-south width of the clear cut. For the 13 small clear cuts sampled, apparently no relationship exists between stocking of either Douglas-fir or all species and size of clear cut, average hours of shade on clear cut, width of clear cut in narrowest dimension, or average distance of plots from stand edge.

## REGENERATION AND CHARACTERISTICS OF MILACRE PLOTS

The failure of the initial analysis to reveal relationships between stocking levels and gross characteristics of clear cuts prompted a closer look at milacre-plot data on individual clear-cut units. Additional regression analyses were carried out to determine if number of Douglas-fir seedlings per plot was related to (1) hours of shade on plot or (2) distance of plot from seed source. These two analyses were conducted for each of the 13 patch and strip clear cuts. In addition, plot data from each of the major groups of cuttings--east-west strips, north-south strips, and patch clear cuts--were pooled and analyzed in the same manner.

### Stand Shade

Stand shade favored establishment of natural regeneration. On some cuttings, this was apparent simply from examination of plotted data (fig. 1). The statistical analyses revealed that a significant relationship existed between

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[5/] In this paper, "significant" is used in a statistical sense and means that a relationship was shown to exist at the 5-percent level of probability. "Highly significant" means a relationship was shown to exist at the 1-percent level of probability.

hours of shade and number of Douglas-fir seedlings per plot on 8 of 13 units. The pooled data from all three major types of cuttings showed a highly significant correlation between hours of shade and number of Douglas-fir seedlings per plot.

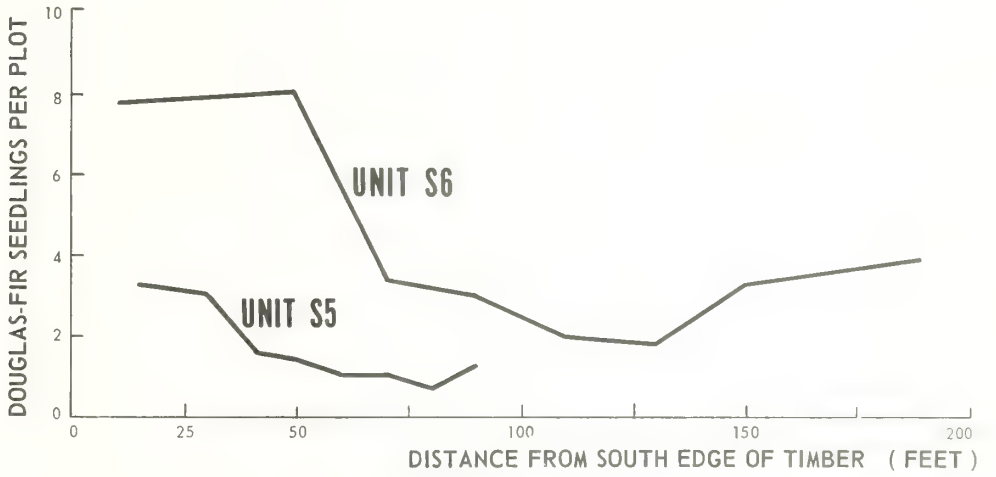


Figure 1.--Relation between stocking and distance from the south edge of timber on two east-west oriented strip clear cuts. Unit S5 is 100 feet wide and unit S6 is 200 feet wide.

In general, the relation between hours of shade and regeneration was more marked on east-west strip clear cuts and patch clear cuts than on north-south strip clear cuts. A partial explanation of differences between units is provided by Silen.[6/] He found seedlings must be exposed to a high soil surface temperature for a continuous period of time before heat damage occurs to the seedling. Apparently, intermittent sunlight is less damaging than an equal duration of continuous sunlight. Only part of the variation between units can be explained in this way; other factors, such as time of day plot receives stand shade, pattern of ground shade, and microexposure, doubtless play a major role.

How much shade can be expected from a particular stand edge? The theoretical relationship of tree height, percent slope, angle of sun, and stand shade is shown in figure 2. In practice, this relationship is modified by the continuity and crown condition of the stand providing shade. Plotted results from two units (fig. 1) indicate that a timber edge on the south affects a smaller

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[6/] See footnote 3, p. 4.

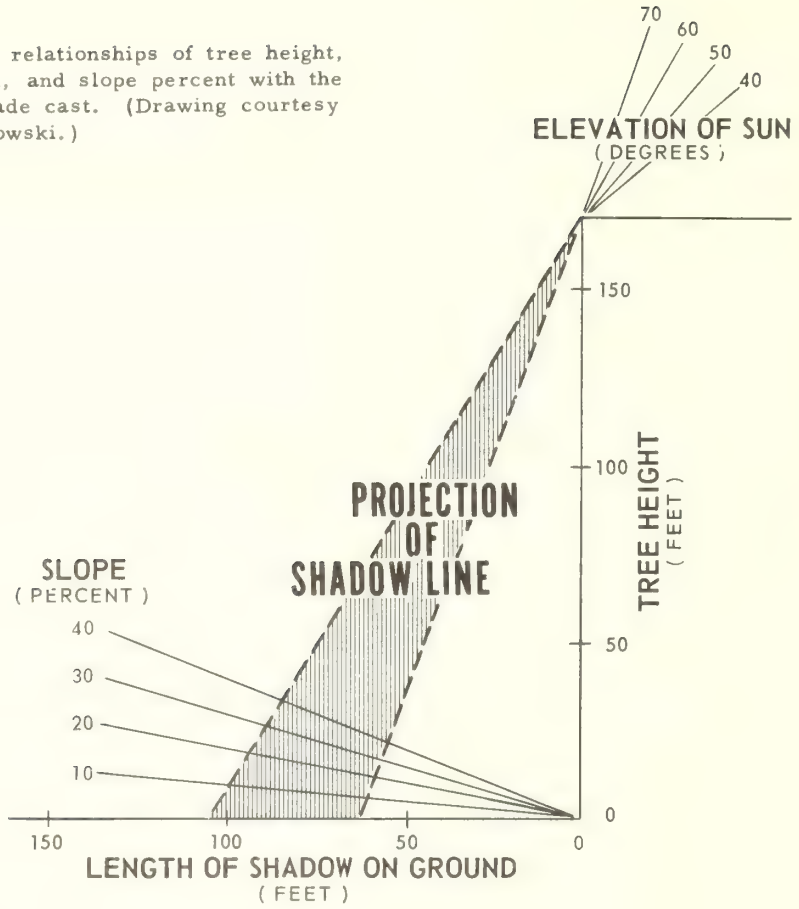


Figure 2.--Theoretical relationships of tree height, elevation of the sun, and slope percent with the amount of stand shade cast. (Drawing courtesy of Dr. H. J. Gratkowski.)

area than indicated by the diagram. The differences between the obviously shade-influenced areas on these units (approximately 35 feet and 70 feet) reflect differences in the shade effects of the timber edge.[7/]

Distance from Seed Source

The number of Douglas-fir seedlings per plot was generally not related to distance from seed source. All portions of strip and patch clear cuts were within 200 feet (and usually much less) of a timber edge. Since Douglas-fir seed is readily carried much greater distances (Isaac, 1943), a relation between stocking and distance from seed source would not be expected on these units. On a few cuttings, there were significant relations between regeneration and distance

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7/ These units were chosen because the relationship between stand shade and stocking is least influenced by extraneous factors such as roads and cutting boundary irregularities.

from stand edge, but these probably resulted from the partial relationship which exists between hours of shade and distance from stand edge. However, on the staggered-setting clear cut, the relation between stocking and distance from stand edge was highly significant:

| Distance from stand edge | Total plots | Plots stocked | Percent stocked |
|---|---|---|---|
| Under 200 feet | 106 | 52 | 49 |
| Over 200 feet | 119 | 10 | 8 |

Worthington (1953) reported similar results after studying regeneration on a large clear cut and some small patch clear cuts 1.2 to 4.0 acres in size in western Washington. Distance from stand edge affected stocking only beyond 500 feet on the large clear cut. None of the small patch cuts he studied had sample points over 500 feet from stand edge, and no relation between stocking and distance from stand edge was therefore found on these units.

This also explains the lack of relationship between clear cut size and stocking mentioned earlier. The patch and strip clear cuts were simply too small to show such a relation. Lavender et al. (1956) studied much larger clear cuts and concluded there was no relation between the size of clear cut and regeneration.

## DISCUSSION OF THE MODIFIED CUTTINGS

### North-South Strip Clear Cuts

Although north-south strip clear cuts had the poorest stocking of the modified cuttings, they were surprisingly well stocked considering the severity of the site. Analysis of the individual north-south strip clear cuts generally indicated no significant relation between number of Douglas-fir seedlings per plot and hours of shade or distance from seed source. Lack of a relation between shade hours and regeneration can be explained, at least in part, by the continuous rather than intermittent character of the shade (fig. 3). There does not appear to be any significant relation between stocking and width of north-south strip.

### East-West Strip Clear Cuts

The long timber edge available for shading regeneration on the east-west strip clear cuts was probably responsible for superior stocking on these units. Furthermore, much of the shading was of the intermittent type. Analysis of data from individual units and of the pooled data indicated the number of Douglas-fir seedlings per plot was significantly related to hours of shade.

Figure 3.--Pattern of shading on north-south oriented strip clear cuts. Top, in the morning; middle, at midday; bottom, in the afternoon.

## Patch Clear Cuts

Stocking of patch clear cuts was generally intermediate between the east-west and north-south strip clear cuts. As a group, the patch clear cuts showed a consistent relationship between shade and number of Douglas-fir seedlings per plot. Two exceptions were units G2 and G5. Part of unit G2 was a low swampy area which offered little mineral seedbed. More than half of the stocked plots contained western hemlock and/or western redcedar; and 29 percent of the plots were stocked with Douglas-fir. Unit G5 had a road as its southern boundary and the effective environment of this clear cut was larger than its half-acre size would indicate. In addition, a second unit just across the road from G5 was cut in the spring of 1959. This disturbance made it impossible to obtain a valid estimate of amount of shading during the previous 4 years.

Most references to strip and patch clear cutting list the main advantage as a provision for an effective seed source (Haig et al., 1941; Hawley and Smith, 1954; Heinselman, 1959; Lexen, 1949). Hawley and Smith (1954) mention in addition that "...this kind of modification [strips or patches] may also be employed...to create an environmental condition intermediate between the protection of a shelterwood and the drastic exposure of a large clear cut area." Troup (1952) emphasizes the protective function of such cuttings. A system known as Wagner's "Blendersaumschlag" involves narrow strip cuttings oriented east and west which progress from north to south with the specific objective of protecting seedlings from the sun on the strip being regenerated. In European clear-strip systems, cuttings are often restricted to widths no more than the height of adjacent forest in order to secure side protection from the sun for either artificial or natural regeneration. Results of the current study suggest that patch and strip clear cuttings for Douglas-fir are primarily of value in aiding seedling establishment.

## Seed-Tree Cutting

The seed-tree cutting was a small staggered-setting on which three dozen Douglas-firs were left on two-thirds of the area to supply seed and shade (fig. 4). Trees were selected for vigor and at a spacing of approximately 120 feet; slash was pulled away from the seed trees during logging to prevent damage during slash burning.

Figure 4.--General view of seed-tree cutting.

The seed-tree portion of unit 5C was well stocked 4 years after logging (table 2). An important factor in prompt seedling establishment was probably the shade cast by seed trees. Garman (1955) found that a full-crowned, mature Douglas-fir seed tree gives temporary protection to an area of one-third acre during critical times of the year. Mineral seedbed resulting from yarding and slash-disposal operations and additional seed produced by seed trees were other important factors. Seed trees have been found to be heavier cone producers and more efficient distributors of seed than marginal timber (Garman, 1951; Isaac, 1940). Poorest stocking was on the portion of the unit without seed trees, but a statistical comparison was not possible because of variations in slope, exposure, steepness, and edge-shade effects.

Careful selection of sound, vigorous, and apparently windfirm seed trees and prevention of damage to them during logging-slash burning resulted in almost 100-percent seed-tree survival. None of the Douglas-fir trees left in 1955 had blown down and only two had died from exposure as of September 1961. Most were full crowned and had been producing seed.

Several studies of Douglas-fir regeneration have indicated the value of seed trees for regeneration. Garman (1955) found that shade definitely improved seedling survival in British Columbia. He felt that shade from two to eight seed trees per acre was indicated on severe sites and that cutting of Douglas-fir would eventually evolve to harvesting in 300-foot-wide strips (on good sites) and a shelterwood system on more severe sites. He concluded, "Douglas-fir should be cut by a method that leaves the shade of scattered seed trees." Bever (1954), following a study of factors affecting natural regeneration in central western Oregon, concluded the seed-source value of seed trees was higher than marginal timber or seed blocks. In contrast, early studies of seed trees indicated mortality, wind, logging, and slash burning quickly destroyed most of the trees (Isaac, 1940).

## CONCLUSIONS

Strip and patch clear cuttings and a seed-tree cutting were adequately stocked with seedlings of Douglas-fir and associated species within 4 years after logging and slash burning. There was, however, a great deal of variability in level of stocking between and within the experimental cuttings. A staggered-setting clear cut of comparable age was not adequately stocked. Quantity of Douglas-fir regeneration was not related to gross characteristics of the cutting areas such as size or width. However, stocking of seedlings of all species was related to the north-south width of the clear cut. Analyses of the plot data from individual clear cuts showed that, of several factors studied, number of hours of stand shade on a plot was most closely related to number of Douglas-fir seedlings. Regeneration was not related to distance from seed source on the relatively small patch and strip clear cuts.

The chief value of modified cutting systems appeared to be in seedling establishment, particularly through reduction of insolation losses. Intermittent

shade may have been more effective than a similar amount of shade received in a single period of time, although this was not demonstrated conclusively.

It is recommended that consideration be given to the use of modified cutting methods such as east-west strip clear cuts, small patch clear cuts, and seed-tree cuttings to improve natural restocking of Douglas-fir on sites difficult to regenerate. Such cuttings should be laid out primarily to provide shade and secondarily to favor seed dispersal.

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This paper was developed from a thesis "Regeneration patterns on some modified staggered-setting clearcuts on the H. J. Andrews Experimental Forest" (1961) written in partial fulfillment of the requirements for the degree of Master of Science, Oregon State University.

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# GROWTH and YIELD RECORDS from well-stocked stands of DOUGLAS-FIR

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A summary of data and analyses resulting from the oldest permanent growth plots in the Pacific Northwest.

by R. L. WILLIAMSON

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# INTRODUCTION

In the early 1900's, when American forestry was in its infancy, foresters sensed the tremendous growth potential of Douglas-fir but had only sketchy knowledge of its development in natural, young-growth stands. Industry also quickly recognized the place of Douglas-fir as the Pacific Northwest's most important timber tree—a position it continues to occupy. Since wise management of the species depended upon accurate yield forecasts, the Forest Service began early to study Douglas-fir on a systematic, regionwide basis. A primary Forest Service objective was to obtain a solid foundation for growth and yield estimates through periodic sampling of nearly pure, well-stocked stands.

From 1909 to 1939, numerous permanent sample plots were established under the direction of E. J. Hanzlik, J. V. Hofmann, R. E. McArdle, W. H. Meyer, T. T. Munger, and W. Peterson of the Pacific Northwest Forest and Range Experiment Station. Though some plots have been abandoned for various reasons, the 31 remaining have been remeasured at approximate 5-year intervals since time of establishment. In 1962, the sampled stands ranged in age from 77 to 121 years. This summary of plot records spans periods of 22 to 47 years.

Foresters with experience in sample plot establishment will appreciate the difficulties faced by earlier workers in finding stands that were "just right." The objective was 1-acre plots, but in some cases lack of stand uniformity necessitated smaller plots. Access posed problems of a magnitude seldom encountered today. In 1910, for example, a full day by stage, rowboat, and foot travel was required to cover the 30 miles separating three plots on the Willamette drainage from Eugene, Oreg.--an hour's drive by car today (Munger, 1946b).

These 31 plots--the oldest in the Douglas-fir region--have witnessed many of the growing pains associated with development of plot establishment and tree measurement techniques over the past 50 years. Some of the earliest plots were established on a surface instead of a horizontal area basis. Calipers, used in the earlier measurements, gave way to the more accurate and convenient diameter tape about 1920. Similarly, introduction of the Abney level about 1925 considerably improved height determinations formerly made by the Forest Service hypsometer. Some of the first tree tagging failed to follow a systematic pattern. This oversight elicited a number of caustic notes which were entered in the office reports by later observers.

This paper is intended to (1) acquaint the reader with the 31 surviving plots, (2) make available the wealth of statistical data derived from these plots, and (3) describe briefly some of the knowledge yielded by analysis of the plot data.

# PLOT DESCRIPTIONS

One of the most striking features of these plots is their consistent substantiation of normal growth and yield predictions for natural stands of Douglas-fir. The few exceptions have been due to persistent and heavy bark beetle and root rot attack. When these attacks ceased, trends toward normality resumed.

Each plot was chosen initially for its good stocking. Underbrush, usually lacking during early measurements, has gradually increased on most plots. The implications of this trend in regard to reproduction of managed stands warrant further study.

General descriptive data of all 31 plots are outlined in table 1. Tables 2 to 8 present the cumulative statistics of the live stand through the latest field examination. Supplementary notes on plot location and history appear on the page facing each table.

# Table 1.--Description of permanent sample plots

| National Forest and plot numbers | Established | | Legal description | | | Topographic features | | | Annual precipitation |
|---|---|---|---|---|---|---|---|---|---|
| | Year | By | Section | Township | Range[1] | Elevation | Slope | Aspect | |
| | | | | | | Feet | Percent | | Inches |
| Willamette: | | | | | | | | | |
| 1, 2, 3 | 1910 | Munger | 19 | 20 S. | 2 E. | 700 | 0-30 | N. | 48 |
| Siuslaw: | | | | | | | | | |
| 4, 5 | 1911 | Hanzlik | 6 | 16 S. | 8 W. | [2] 800 | 15-25 | S.; SW. | -- |
| 6, 7, 8 | 1911 | Hanzlik, Meyer | -- | -- | -- | [2] 1,300 | ([2] [3]) | W.[2] | -- |
| 9, 10 | 1926 | Meyer | 21, 22 | 15 S. | 9 W. | -- | 20-40 | NE. | -- |
| Wind River:[4] | | | | | | | | | |
| 4, 90 | 1914, 1939 | Hofmann, Peterson | 13 | 4 N. | 7½ E. | 1,300 | 5-50 | W.; E. | 100 |
| 5 | 1914 | Hofmann | 13 | 4 N. | 7½ E. | 1,400 | 65-100 | E. | -- |
| 2, 9 | 1914, 1924 | Hofmann, McArdle | 34 | 5 N. | 7 E. | 2,600 | 2-15 | E. to NE.; N. to NW. | -- |
| Olympic: | | | | | | | | | |
| 1, 2 | 1926 | Meyer | 34 | 27 N. | 2 W. | 100 | 0-60 | W. to NW. | 50 |
| 3, 4 | 1926 | Meyer | 24 | 29 N. | 3 W. | 200 | 30-60 | W. to SW. | 35 |
| Gifford Pinchot: | | | | | | | | | |
| 1 to 5 | 1927 | Meyer | 7, 8 | 11 N. | 8 E. | 1,800 | 0-10 | S. | 61 |
| 7, 9 | 1927 | Meyer | 6 | 12 N. | 7 E. | -- | 0-50 | S. to SE. | -- |
| Snoqualmie: | | | | | | | | | |
| 1, 2 | 1928 | Meyer | 16 | 14 N. | 8 E. | 2,500 | 15-20 | SW. | 81 |
| Mt. Hood: | | | | | | | | | |
| 1, 2, 3 | 1930 | Meyer | 14 | 3 S | 7 E. | 1,900 | 60 | NE. to SE. | 100 |

[1] East or west of the Willamette meridian.

[2] Data for plot 8, but representative of the other two.

[3] Ridgetop.

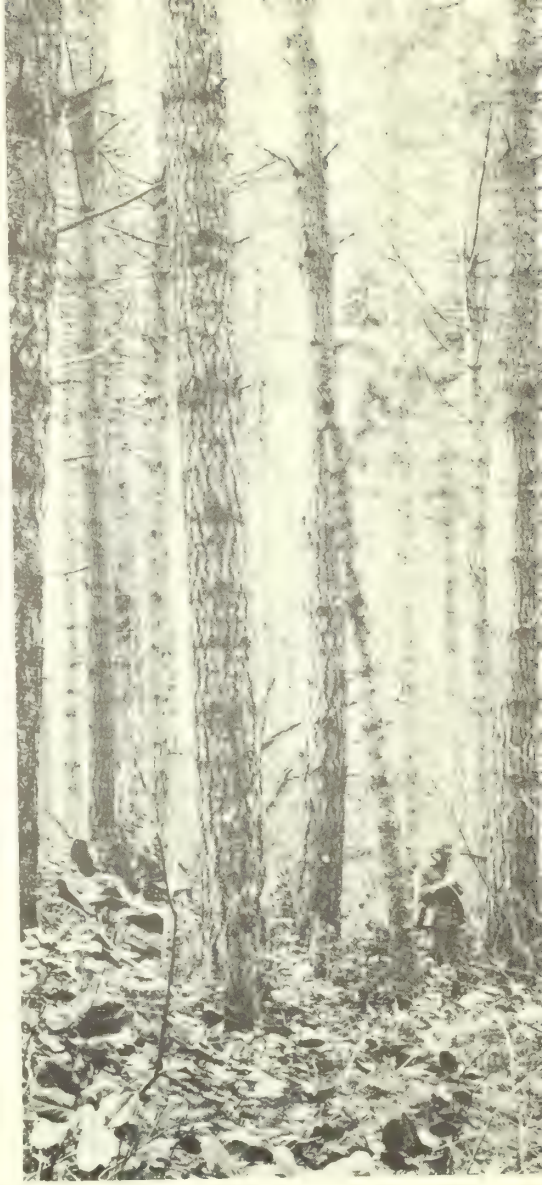
[4] Wind River District, Gifford Pinchot National Forest.

## WILLAMETTE PLOTS 1, 2, and 3

The 53-year history of these plots covers a longer span of years than that of any other group of permanent sample plots in the Douglas-fir region. Located about 30 miles southeast of Eugene, Oreg., these plots are on a level bench above Lookout Point Reservoir on the Middle Fork of the Willamette River.

At plot establishment, Munger noted that many trees bore basal fire scars or had forked or bayonet tops from wind and ice storms. These injuries had no apparent effect on subsequent gross volume growth, however. In addition, the stands have continued normal development after a severe wind and snow storm in the 1915-20 period plus a bark beetle attack from 1935-45.

Plot 1 – 10,316 cubic feet at age 69 (1925).



Plot 3 – 11,864 cubic feet at age 69 (1925).

# Table 2.--Willamette permanent sample plots 1, 2, and 3; statistics of the live stand (values on horizontal acre basis)

| Plot No. | Month and year measured | Age, years | Growth period, years | Horizontal area, acres | Site index, feet | Site quality | Stand 2.6 inches and more in d.b.h. | | | | | | | | Conifer stand | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Number of trees | | Basal area, square feet | | Average d.b.h., inches | | Average height of conifers, feet | Volume of conifers, cubic feet | 6.6+ inches d.b.h. | | 11.6+ inches d.b.h. | | Dominants and codominants | |
| | | | | | | | Conifers | Hardwoods | Conifers | Hardwoods | Conifers | Hardwoods | | | Number of trees | Volume, board feet (International ¼-inch rule) | Number of trees | Volume, board feet (Scribner rule) | Average d.b.h., inches | Average height, feet |
| 1 | 4/10 | 54 | -- | 1.00 | 157 | II- | 188 | 28 | 181.2 | 8.7 | 13.3 | 7.6 | 103 | 7,354 | 165 | 48,420 | 100 | 29,010 | 18.3 | 119 |
| | 5/15 | 59.5 | 5.5 | | 153 | II+ | 175 | 13 | 197.2 | 4.0 | 14.3 | 7.5 | 116 | 8,709 | 159 | 60,270 | 106 | 37,440 | 19.9 | 131 |
| | 6/20 | 64.5 | 5 | | 157 | II- | 149 | 9 | 207.0 | 3.5 | 16.0 | 8.4 | 126 | 9,528 | 143 | 68,590 | 110 | 44,070 | 21.6 | 137 |
| | 3/25 | 69 | 4.5 | | 160 | II- | 141 | 7 | 218.2 | 2.8 | 16.9 | 8.6 | 132 | 10,316 | 138 | 74,260 | 111 | 49,280 | 20.5 | 139 |
| | 4/30 | 74 | 5 | | 161 | II- | 137 | 7 | 225.0 | 3.1 | 17.4 | 9.0 | 136 | 11,162 | 133 | 82,564 | 112 | 54,128 | 20.7 | 143 |
| | 10/34 | 79 | 5 | | 166 | II | 127 | 7 | 239.1 | 3.0 | 18.6 | 8.9 | 145 | 12,483 | 126 | 92,652 | 111 | 63,754 | 21.2 | 151 |
| | 10/39 | 84 | 5 | | 168 | II | 121 | 8 | 249.0 | 3.2 | 19.4 | 8.6 | 149 | 13,301 | 120 | 100,011 | 109 | 70,145 | 22.3 | 156 |
| | 10/45 | 90 | 5 | | 170 | II | 112 | 7 | 257.1 | 3.4 | 20.4 | 9.4 | 157 | 14,165 | 111 | 108,194 | 106 | 77,713 | 23.7 | 163 |
| | 12/50 | 95 | 6 | | 170 | II | 110 | 7 | 270.5 | 3.4 | 21.2 | 9.4 | 158 | 15,225 | 110 | 116,899 | 105 | 84,666 | 24.2 | 166 |
| | 10/55 | 100 | 5 | | 170 | II | 103 | 7 | 271.4 | 3.4 | 22.1 | 9.4 | 162 | 15,510 | 102 | 119,686 | 101 | 87,686 | 24.3 | -- |
| 2 | 4/10 | 54 | -- | 1.00 | 162 | II- | 214 | 8 | 215.3 | 1.6 | 13.6 | 6.1 | 105 | 8,796 | 201 | 59,235 | 124 | 34,710 | 18.4 | 119 |
| | 5/15 | 59.5 | 5.5 | | 173 | II | 198 | 5 | 231.7 | .8 | 14.6 | 5.4 | 117 | 10,274 | 189 | 71,460 | 127 | 44,040 | 21.1 | 133 |
| | 6/20 | 64.5 | 5 | | 171 | II | 160 | 4 | 226.9 | .6 | 16.1 | 5.2 | 126 | 10,536 | 160 | 74,920 | 122 | 47,860 | 21.9 | 138 |
| | 3/25 | 69 | 4.5 | | 162 | II- | 151 | 3 | 238.7 | .6 | 17.2 | 6.1 | 132 | 11,324 | 151 | 80,370 | 125 | 53,860 | 19.9 | 138 |
| | 4/30 | 74 | 5 | | 168 | II | 149 | 3 | 255.1 | .1 | 17.6 | 2.5 | 136 | 12,485 | 149 | 91,411 | 125 | 60,620 | 21.1 | 144 |
| | 10/34 | 79 | 5 | | 177 | II+ | 136 | 3 | 255.5 | .6 | 18.6 | 6.1 | 145 | 13,274 | 136 | 98,579 | 120 | 67,242 | 21.2 | 151 |
| | 10/39 | 84 | 5 | | 168 | II | 114 | 6 | 239.1 | .9 | 19.6 | 5.3 | 150 | 12,788 | 114 | 96,211 | 107 | 67,716 | 22.3 | 156 |
| | 10/45 | 90 | 5 | | 170 | II | 116 | 3 | 254.6 | .8 | 20.0 | 6.8 | 154 | 13,917 | 108 | 106,811 | 103 | 77,153 | 23.4 | 163 |
| | 12/50 | 95 | 6 | | 170 | II | 109 | 3 | 259.7 | .8 | 20.9 | 6.8 | 158 | 14,654 | 101 | 112,404 | 100 | 81,917 | 24.0 | 166 |
| | 10/55 | 100 | 5 | | 170 | II | 106 | 3 | 261.8 | .8 | 21.3 | 7.1 | 160 | 14,954 | 97 | 115,300 | 95 | 84,641 | 24.4 | -- |
| 3 | 4/10 | 54 | -- | | 151 | III+ | 190 | 18 | 214.7 | 5.3 | 14.4 | 7.3 | 108 | 8,833 | 171 | 59,280 | 118 | 36,380 | 19.4 | 121 |
| | 5/15 | 59.5 | 5.5 | .98 | 158 | II- | 175 | 8 | 233.2 | 2.2 | 15.6 | 7.1 | 121 | 10,406 | 168 | 72,820 | 124 | 46,410 | 21.3 | 133 |
| | 6/20 | 64.5 | 5 | .98 | -- | -- | 157 | 7 | 237.2 | 2.0 | 16.7 | 7.2 | 128 | 10,934 | 154 | 78,090 | 120 | 50,940 | 22.1 | 138 |
| | 3/25 | 69 | 4.5 | .98 | 171 | II | 147 | 6 | 251.3 | 1.7 | 17.7 | 7.2 | 134 | 11,864 | 147 | 86,070 | 120 | 57,290 | 21.4 | 140 |
| | 4/30 | 74 | 5 | 1.00 | 159 | II- | 145 | 3 | 263.2 | .8 | 18.2 | 7.0 | 137 | 12,741 | 145 | 94,155 | 120 | 63,312 | 21.8 | 144 |
| | 10/34 | 79 | 5 | 1.00 | 165 | II- | 131 | 4 | 260.7 | .9 | 19.1 | 6.4 | 146 | 13,628 | 131 | 101,314 | 115 | 69,694 | 21.7 | 152 |
| | 10/39 | 84 | 5 | 1.00 | 168 | II | 127 | 7 | 271.6 | 1.2 | 19.8 | 5.6 | 150 | 14,536 | 127 | 109,504 | 112 | 76,893 | 22.4 | 156 |
| | 10/45 | 90 | 5 | 1.00 | 170 | II | 118 | 2 | 273.1 | .2 | 21.0 | 4.7 | 155 | 15,052 | 112 | 115,212 | 105 | 83,022 | 23.6 | 162 |
| | 12/50 | 95 | 5 | 1.00 | 170 | II | 110 | 2 | 274.7 | .2 | 21.4 | 4.5 | 159 | 15,508 | 103 | 119,320 | 98 | 87,000 | 24.4 | 167 |
| | 10/55 | 100 | 5 | 1.00 | 170 | II | 114 | 2 | 283.7 | .3 | 21.3 | 5.0 | 159 | 16,216 | 100 | 125,272 | 97 | 92,263 | 24.9 | -- |

## SIUSLAW PLOTS 4 to 10

Plots 4 and 5, in the Deadwood Creek drainage near Alpha, Oreg., lie on a spur ridge with parts of the plots extending off the ridgetop onto steep ground. The same is true of plots 6 and 7, which lie on the ridge between Saddle Mountain and Three Buttes, about 900 feet south of the road from Pawn. Plot 8, near plots 6 and 7, and plots 9 and 10, on a bench next to Five Rivers near Paris, are all on gentle, uniform ground.

Unfortunately, the trees on plots 6 and 7 were not tagged in 1911 when the plots were established. At age 38, these were the youngest stands in the growth and yield plots, and 15 years passed before the trees were tagged in 1926. Plots 6 and 7 were very dense and suffered severe losses from windthrow and snowbreak.

In the same period, plots 9 and 10 suffered even heavier mortality from a variety of causes, losing about 30 percent of their cubic volume. The recovery of these stands at ages of around 90 years is of particular silvicultural interest. A stand map was prepared for plot 9 in 1926.

Plot 5 – Showing stand density at age 65 (1926).

Plot 10 – Average diameter 23.1 inches at age 67 (1926).

# Table 3.--Siuslaw permanent sample plots 4, 5, 6, 7, 8, 9, and 10; statistics of the live stand (values on horizontal acre basis)

| Plot No. | Month and year measured | Age, years | Growth period, years | Horizontal area, acres | Site index, feet | Site quality | Stand 2.6 inches and more in d.b.h. | | | | | | | | Stand 6.6+ inches d.b.h. | | | Stand 11.6+ inches d.b.h. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Number of trees | | Basal area, square feet | | Average d.b.h., inches | | Average height of conifers, feet | Volume of conifers, cubic feet | Number of trees | | Volume of conifers, board feet (International ¼-inch rule) | Number of trees | | Volume of conifers, board feet (Scribner rule) |
| | | | | | | | Conifers | Hardwoods | Conifers | Hardwoods | Conifers | Hardwoods | | | Conifers | Hardwoods | | Conifers | Hardwoods | |
| 4 | 8/11 | 50 | | 0.399 | 170 | II | 298 | 60 | 292.8 | 11.9 | 13.4 | 6.0 | 102 | 11,980 | 273 | 18 | 79,290 | 185 | 0 | 48,350 |
| | 9/16 | 55 | 5 | | 172 | II | 273 | 38 | 329.4 | 9.1 | 14.9 | 6.6 | 112 | 14,150 | 263 | 18 | 96,870 | 192 | 0 | 61,620 |
| | 10/21 | 60 | 5 | | 167 | II | 238 | 25 | 346.6 | 6.7 | 16.4 | 7.0 | 120 | 15,520 | 233 | 12 | 109,000 | 190 | 0 | 71,870 |
| | 9/26 | 65 | 5 | | 167 | II | 228 | 23 | 364.1 | 6.5 | 17.1 | 7.2 | 125 | 16,890 | 223 | 12 | 120,450 | 192 | 0 | 81,510 |
| | 9/31 | 70 | 5 | | 176 | II+ | 218 | 23 | 392.1 | 6.9 | 18.2 | 7.4 | 138 | 19,435 | 213 | 15 | 142,770 | 190 | 2 | 100,840 |
| | 9/36 | 75 | 5 | | 175 | II | 198 | 10 | 408.4 | 4.5 | 19.2 | 9.0 | 145 | 21,120 | 198 | 10 | 157,390 | 185 | 0 | 111,110 |
| | 9/41 | 80 | 5 | | 174 | II | 180 | 10 | 420.5 | 4.5 | 20.8 | 9.0 | 151 | 22,125 | 180 | 10 | 167,159 | 175 | 0 | 119,726 |
| | 10/46 | 85 | 5 | | 174 | II | 180 | 10 | 446.4 | 4.5 | 21.3 | 9.0 | 155 | 24,253 | 180 | 10 | 184,868 | 175 | 0 | 134,028 |
| | 9/51 | 90 | 5 | | -- | -- | 173 | 10 | 463.2 | 5.3 | 22.2 | 9.8 | 159 | 25,716 | 173 | 10 | 196,086 | 168 | 0 | 143,848 |
| 5 | 8/11 | 50 | | .455 | 175 | II | 382 | 0 | 236.3 | -- | 10.6 | -- | 102 | 9,895 | 336 | 0 | 63,390 | 110 | 0 | 26,370 |
| | 9/16 | 55 | 5 | | 177 | II+ | 347 | 0 | 255.1 | -- | 11.6 | -- | 109 | 11,180 | 331 | 0 | 74,450 | 134 | 0 | 35,500 |
| | 10/21 | 60 | 5 | | 162 | II- | 297 | 0 | 256.3 | -- | 12.6 | -- | 116 | 11,625 | 290 | 0 | 79,590 | 145 | 0 | 42,290 |
| | 9/26 | 65 | 5 | | 160 | II- | 286 | 0 | 267.0 | -- | 13.1 | -- | 119 | 12,395 | 279 | 0 | 86,210 | 152 | 0 | 47,890 |
| | 9/31 | 70 | 5 | | 160 | II- | 268 | 0 | 280.0 | -- | 13.8 | -- | 124 | 13,415 | 266 | 0 | 95,850 | 154 | 0 | 54,940 |
| | 9/36 | 75 | 5 | | 160 | II- | 230 | 0 | 281.8 | -- | 15.0 | -- | 131 | 14,110 | 228 | 0 | 101,810 | 151 | 0 | 62,280 |
| | 9/41 | 80 | 5 | | 159 | II- | 202 | 0 | 285.6 | -- | 16.1 | -- | 135 | 14,328 | 200 | 0 | 104,938 | 149 | 0 | 67,283 |
| | 10/46 | 85 | 5 | | 164 | II- | 189 | 0 | 288.3 | -- | 16.7 | -- | 144 | 15,474 | 189 | 0 | 114,835 | 147 | 0 | 75,298 |
| | 9/51 | 90 | 5 | | -- | -- | 185 | 0 | 298.1 | -- | 17.2 | -- | 147 | 16,218 | 185 | 0 | 120,224 | 147 | 0 | 81,013 |
| 6 | 8/11 | 38 | | .932 | 188 | I- | 199 | 9 | 187.2 | 3.8 | 13.1 | 9.0 | 95 | 7,060 | 181 | 4 | 44,920 | 101 | 2 | 25,280 |
| | 9/16 | 45 | 5 | | -- | -- | 183 | 5 | 208.2 | 3.6 | 14.4 | 11.1 | 105 | 8,415 | 177 | 5 | 56,130 | 115 | 3 | 33,760 |
| | 10/21 | 48 | 5 | | -- | -- | 156 | 0 | (1/) | (1/) | (1/) | (1/) | (1/) | (1/) | 153 | 0 | (1/) | 131 | 0 | (1/) |
| | 9/26 | 53 | 5 | | 187 | I- | 150 | 1 | 241.9 | .6 | 15.2 | 10.0 | 127 | 11,225 | 149 | 1 | 80,110 | 131 | 0 | 53,880 |
| | 9/31 | 58 | 5 | | 190 | I- | 142 | 0 | 259.4 | -- | 18.8 | -- | 137 | 12,655 | 142 | 0 | 92,950 | 130 | 0 | 63,240 |
| | 9/36 | 63 | 5 | | 192 | I- | 128 | 0 | 265.6 | -- | 19.5 | -- | 148 | 13,910 | 128 | 0 | 103,820 | 126 | 0 | 73,710 |
| | 9/41 | 68 | 5 | | 190 | I- | 109 | 0 | 256.4 | -- | 20.7 | -- | 152 | 13,550 | 109 | 0 | 101,819 | 108 | 0 | 73,024 |
| | 10/46 | 73 | 5 | | 194 | I- | 104 | 0 | 270.3 | -- | 21.8 | -- | 162 | 15,278 | 104 | 0 | 117,360 | 103 | 0 | 86,007 |
| | 9/51 | 78 | 5 | | -- | -- | 98 | 0 | 274.8 | -- | 22.7 | -- | 166 | 15,762 | 98 | 0 | 121,548 | 98 | 0 | 90,310 |
| 7 | 8/11 | 38 | | .441 | 188 | I- | 236 | 11 | 151.0 | 5.7 | 10.8 | 9.6 | 87 | 5,445 | 202 | 11 | 32,520 | 82 | 7 | 14,440 |
| | 9/16 | 43 | 5 | | -- | -- | 161 | 14 | 156.2 | 9.2 | 13.3 | 11.1 | 102 | 6,270 | 161 | 14 | 40,920 | 93 | 7 | 22,120 |
| | 10/21 | 48 | 5 | | -- | -- | 136 | 0 | (1/) | (1/) | (1/) | (1/) | (1/) | (1/) | 138 | 0 | (1/) | 120 | 0 | (1/) |
| | 9/26 | 53 | 5 | | 185 | I- | 132 | 5 | 190.4 | 5.6 | 16.3 | 13.5 | 124 | 8,805 | 132 | 5 | 62,320 | 107 | 5 | 39,880 |
| | 9/31 | 58 | 5 | | 187 | I- | 120 | 5 | 205.4 | 4.0 | 17.7 | 13.5 | 134 | 9,960 | 120 | 5 | 72,480 | 109 | 5 | 49,070 |
| | 9/36 | 63 | 5 | | 194 | I- | 111 | 2 | 219.2 | 2.0 | 19.0 | 13.8 | 147 | 11,455 | 111 | 2 | 85,360 | 104 | 2 | 59,690 |
| | 9/41 | 68 | 5 | | 190 | I- | 79 | 2 | 199.4 | 1.9 | 21.5 | 13.8 | 154 | 10,587 | 79 | 2 | 79,684 | 79 | 2 | 57,793 |
| | 10/46 | 73 | 5 | | 196 | I- | 77 | 2 | 217.1 | 1.8 | 22.7 | 13.8 | 165 | 12,367 | 77 | 2 | 95,217 | 77 | 2 | 67,925 |
| | 9/51 | 78 | 5 | | -- | -- | 75 | 0 | 227.6 | -- | 23.6 | -- | 168 | 13,163 | 75 | 0 | 101,677 | 75 | 0 | 76,303 |
| 8 | 9/36 | 53 | | 1.000 | 178 | II+ | 234 | 0 | 244.8 | -- | 13.8 | -- | 114 | 10,985 | 232 | 0 | 75,880 | 147 | 0 | 44,600 |
| | 9/41 | 58 | | | 176 | II+ | 228 | 0 | 266.4 | -- | 14.8 | -- | 122 | 12,480 | 227 | 0 | 88,550 | 151 | 0 | 54,420 |
| | 9/46 | 63 | 5 | | 172 | II | 191 | 0 | 265.6 | -- | 16.0 | -- | 127 | 12,760 | 191 | 0 | 91,430 | 150 | 0 | 58,810 |
| | 9/51 | 68 | 5 | | 173 | II | 188 | 0 | 273.3 | -- | 17.3 | -- | 134 | 13,493 | 188 | 0 | 98,546 | 148 | 0 | 66,047 |
| | 10/56 | 73 | 5 | | 169 | II | 153 | 0 | 281.8 | -- | 18.4 | -- | 137 | 14,030 | 153 | 0 | 103,852 | 142 | 0 | 70,970 |
| | 9/61 | 78 | 5 | | -- | -- | 137 | 0 | 294.5 | -- | 19.1 | -- | 140 | 14,882 | 137 | 0 | 110,486 | 138 | 0 | 76,558 |
| 9 | 9/36 | 53 | | 1.000 | 178 | I- | 117 | 0 | 286.4 | -- | 21.2 | -- | 163 | 16,340 | 117 | 0 | 125,790 | 115 | 0 | 91,865 |
| | 9/41 | 58 | | | 181 | I- | 102 | 0 | 274.5 | -- | 21.2 | -- | 168 | 16,025 | 102 | 0 | 124,290 | 102 | 0 | 92,144 |
| | 9/46 | 63 | | | 184 | I | 86 | 0 | 266.0 | -- | 18.8 | -- | 178 | 16,370 | 86 | 0 | 128,780 | 86 | 0 | 95,098 |
| | 9/51 | 68 | | | 183 | I- | 83 | 0 | 288.0 | -- | 20.3 | -- | 183 | 17,452 | 83 | 0 | 90,850 | 83 | 0 | 89,530 |
| | 9/56 | 73 | | | 184 | I- | 80 | 0 | 291.8 | -- | 20.5 | -- | 187 | 17,07 | 80 | 0 | 96,030 | 80 | 0 | 94,151 |
| | 9/61 | 78 | | | -- | -- | 48 | 0 | 297.4 | -- | 21.5 | -- | 190 | 17,620 | 48 | 0 | 100,368 | 48 | 0 | 96,877 |
| 10 | 9/36 | 53 | | 1.000 | 201 | I | 124 | 0 | 234.8 | -- | 19.8 | -- | 161 | 15,80 | 126 | 0 | 117,320 | 122 | 0 | 94,[illegible] |
| | 9/41 | 58 | | | 200 | I- | 109 | 0 | 231.2 | -- | 21.2 | -- | 173 | 15,780 | 109 | 0 | 121,330 | 105 | 0 | 94,[illegible] |
| | 9/46 | 63 | | | 199 | I | 87 | 0 | 233.1 | -- | 22.3 | -- | 176 | 16,860 | 87 | 0 | 116,260 | 87 | 0 | 94,[illegible] |
| | 9/51 | 68 | 5 | | 200 | I | 83 | 0 | 252.0 | -- | 24.4 | -- | 185 | 17,130 | 83 | 0 | 87,430 | 83 | 0 | 94,[illegible] |
| | 9/56 | 73 | | | 201 | I | 83 | 0 | 269.4 | -- | 24.4 | -- | 189 | 18,049 | 83 | 0 | 96,374 | 83 | 0 | 94,[illegible] |
| | 9/61 | 78 | | | -- | -- | 81 | 0 | 279.6 | -- | 25.7 | -- | 192 | 18,831 | 81 | 0 | 101,444 | 81 | 0 | 94,[illegible] |

## WIND RIVER PLOTS 2, 4, 5, 9, and 90

Plots 2 and 9 are adjacent to the Carson-Guler road, about 11 miles from Hemlock Ranger Station near Carson, Wash. Plots 4, 5, and 90 are along Panther Creek near the Warren Gap road, about 7 miles from the Ranger Station.

These stands have suffered recurrently from wind and ice storms and from bark beetle attacks. Heavy mortality has occurred consistently since 1924, and stand deterioration has been evident since 1935—stand age 94 years. Bark beetle attacks have been the chief obstacle to recovery, conditions being so severe that part of plot 5 was clear cut when an adjacent patch of killed and infested timber was harvested. These plots have obviously suffered somewhat more than "normal" mortality.

The 47-year data record for plots 2, 4, and 5 provided an opportunity to smooth out the curve of the erratic losses due to mortality and derive some consistent expressions of mean and periodic annual increment. Adjusted gross volumes were obtained through regression analysis of volume-basal area ratios with respect to age. Regression analysis also revealed that mortality increased with stand age, though age accounted for only 10 percent of the total variation. Gross growth for the 47-year period agreed closely with gross yield tables (Staebler, 1955b), but the periodic annual increment curve was skewed negatively relative to the gross yield table curve. This skewness reflected the heavy mortality, below stand age 100, noted previously. This mortality also reduced net growth rates to about 70 percent of normal.

Plot 4 – 12,140 cubic feet at age 88 (1929).

Plot 9 – After heavy mortality in 1919-29 period (1929).

# Table 4.--Wind River permanent sample plots 2, 4, 5, 9, and 90; statistics of the live stand[1/] (values on horizontal acre basis)

| Plot No. | Month and year measured | Age, years | Growth period, years | Horizontal area, acres | Site index, feet | Site quality | Stand 2.6 inches and more in d.b.h. | | | | | | | | 6.6+ inches d.b.h. | | 11.6+ inches d.b.h. | | Dominants and codominants | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Number of trees | | Basal area, square feet | | Average d.b.h., inches | | Average height, feet | Volume, cubic feet | Number of trees | Volume, board feet (International ¼-inch rule) | Number of trees | Volume, board feet (Scribner rule) | Average d.b.h., inches | Average height, feet |
| | | | | | | | Conifers | Other than Douglas-fir | Conifers | Other than Douglas-fir | Conifers | Other than Douglas-fir | | | | | | | | |
| 2 | 1914 | 72 | | 0.995 | 150 | III+ | 160 | 8 | 219.8 | 2.2 | 15.4 | 7.1 | 112 | 9,247 | 146 | 63,390 | 116 | 42,270 | 19.6 | 124 |
| | 1919 | 77 | 5 | | 147 | III+ | 149 | 7 | 236.3 | 2.1 | 16.8 | 7.4 | 123 | 10,625 | 141 | 75,310 | 117 | 50,400 | 19.7 | 132 |
| | 9/24 | 83 | 6 | | 144 | III | 145 | 7 | 256.1 | 2.1 | 17.7 | 7.4 | 130 | 11,953 | 139 | 86,090 | 121 | 58,850 | 21.1 | 138 |
| | 9/29 | 88 | 5 | | 142 | III | 131 | 5 | 254.0 | .8 | 18.8 | 5.5 | 130 | 11,524 | 126 | 83,468 | 112 | 57,320 | 21.5 | 136 |
| | 9/34 | 93 | 5 | | 140 | III | 110 | 5 | 228.5 | 1.0 | 19.5 | 6.0 | 133 | 10,681 | 104 | 77,799 | 97 | 54,357 | 21.9 | 139 |
| | 9/39 | 98 | 5 | | 145 | III | 108 | 4 | 238.6 | .9 | 20.1 | 6.4 | 139 | 11,427 | 103 | 84,406 | 97 | 59,175 | 22.4 | 144 |
| | 5/45 | 103 | 5 | | 146 | III+ | 110 | 8 | 251.9 | .8 | 20.5 | 4.2 | 141 | 12,293 | 100 | 91,106 | 96 | 64,514 | 23.8 | 148 |
| | 8/50 | 109 | 6 | | -- | -- | 108 | 13 | 255.5 | .9 | 20.9 | 4.1 | 140 | 12,582 | 95 | 92,878 | 94 | 66,557 | 24.2 | 149 |
| | 8/55 | 114 | 5 | | 147 | III+ | 93 | 7 | 234.6 | .9 | 21.5 | 4.9 | 142 | 11,441 | 86 | 85,029 | 84 | 60,726 | 24.3 | 150 |
| | 9/60 | 119 | 5 | | 144 | III | 92 | 7 | 243.7 | 1.2 | 22.1 | 5.7 | 145 | 11,982 | 86 | 89,579 | 83 | 64,265 | 25.0 | 153 |
| 4 | 1914 | 72 | | .975 | 144 | III | 185 | 10 | 215.0 | 4.0 | 14.5 | 8.1 | -- | 8,952 | 177 | 59,910 | 127 | 37,400 | 18.5 | 121 |
| | 1919 | 77 | 5 | | -- | -- | 176 | 8 | 231.0 | 2.6 | 15.4 | 7.3 | -- | 10,047 | 170 | 69,670 | 132 | 44,660 | 17.4 | 124 |
| | 9/24 | 83 | 6 | | -- | -- | 171 | 7 | 249.1 | 2.5 | 16.2 | 8.1 | -- | 11,344 | 166 | 80,510 | 132 | 52,640 | 20.8 | 135 |
| | 9/29 | 88 | 5 | | -- | -- | 158 | 7 | 254.1 | 2.5 | 17.2 | 8.1 | -- | 12,140 | 154 | 87,000 | 128 | 59,440 | 21.0 | 140 |
| | 9/34 | 93 | 5 | | -- | -- | 151 | 8 | 257.5 | 3.0 | 17.7 | 8.3 | -- | 12,265 | 148 | 88,645 | 123 | 59,630 | 21.7 | 141 |
| | 9/39 | 98 | 5 | | 148 | III+ | 143 | 11 | 264.8 | 4.5 | 18.4 | 8.7 | 138 | 12,924 | 137 | 95,295 | 120 | 65,807 | 22.3 | 147 |
| | 5/45 | 103 | 5 | | 152 | III+ | 129 | 11 | 258.1 | 4.9 | 19.7 | -- | 146 | 13,191 | 124 | 98,337 | 112 | 68,268 | 23.4 | 154 |
| | 8/50 | 109 | 6 | | 155 | III+ | 122 | 16 | 253.6 | 4.5 | 20.0 | -- | 147 | 12,588 | 111 | 94,287 | 98 | 65,872 | 24.8 | 156 |
| | 5/56 | 114 | 5 | | 151 | III+ | 113 | 17 | 249.3 | 5.1 | 20.1 | 7.4 | 150 | 12,727 | 96 | 95,842 | 91 | 67,845 | 24.7 | 159 |
| | 9/60 | 119 | 5 | | 153 | III+ | 112 | 21 | 253.0 | 6.8 | 22.6 | 7.8 | 159 | 13,049 | 101 | 97,856 | 88 | 70,304 | 24.8 | 163 |
| 5 | 1914 | 72 | | .938 | 144 | III | 157 | 6 | 232.4 | .8 | 16.5 | 4.9 | -- | 10,292 | 150 | 72,330 | 127 | 48,130 | 20.3 | 133 |
| | 1919 | 77 | 5 | | -- | -- | 154 | 6 | 253.7 | 1.2 | 17.4 | 6.0 | -- | 11,490 | 148 | 81,880 | 131 | 55,630 | 19.3 | 132 |
| | 9/24 | 83 | 6 | | -- | -- | 151 | 6 | 275.7 | 1.5 | 18.3 | 6.4 | -- | 12,651 | 148 | 91,710 | 132 | 63,200 | 21.8 | 138 |
| | 9/29 | 88 | 5 | | -- | -- | 145 | 6 | 289.9 | 1.5 | 19.1 | 6.4 | -- | 13,712 | 143 | 99,930 | 132 | 68,810 | 22.4 | 143 |
| | 9/34 | 93 | 5 | | -- | -- | 127 | 10 | 266.6 | 2.2 | 19.6 | 6.4 | -- | 12,820 | 123 | 94,180 | 115 | 66,310 | 22.8 | 144 |
| | 9/39 | 98 | 5 | | 150 | III+ | 114 | 9 | 254.0 | 1.0 | 20.2 | 7.7 | 143 | 12,323 | 109 | 91,578 | 102 | 64,433 | 23.6 | 149 |
| | 5/45 | 103 | 5 | | 152 | III+ | 107 | 12 | 248.7 | 3.8 | 22.1 | -- | 154 | 12,265 | 102 | 91,249 | 95 | 64,715 | 26.0 | 162 |
| | 8/50 | 109 | 6 | | 153 | III+ | 112 | 20 | 268.4 | 3.7 | 22.3 | -- | 155 | 12,765 | 101 | 95,290 | 93 | 67,984 | 27.2 | 163 |
| | 5/56 | 114 | 5 | [2/].885 | 152 | III+ | 115 | 29 | 258.5 | 8.4 | 20.2 | 7.3 | 145 | 12,995 | 98 | 97,757 | 88 | 70,404 | 25.3 | 158 |
| | 9/60 | 119 | 5 | | 150 | III+ | 120 | 33 | 271.0 | 10.6 | 20.4 | 7.7 | 143 | 13,577 | 99 | 101,553 | 89 | 73,067 | 25.9 | 159 |
| 9 | 9/24 | 83 | | 1.000 | 128 | III- | 210 | 18 | 227.6 | 6.6 | 14.0 | 8.2 | -- | 9,190 | 187 | 60,700 | 137 | 37,830 | 19.9 | 118 |
| | 9/29 | 88 | 5 | | 121 | IV+ | 197 | 18 | 232.9 | 7.9 | 14.7 | 9.0 | 103 | 9,139 | 179 | 60,619 | 137 | 38,378 | 19.1 | 114 |
| | 9/34 | 93 | 5 | | 119 | IV+ | 182 | 19 | 227.1 | 8.6 | 15.1 | 9.1 | 107 | 9,172 | 168 | 61,518 | 131 | 39,414 | 19.1 | 117 |
| | 9/39 | 98 | 5 | | 122 | IV+ | 165 | 17 | 220.7 | 8.2 | 15.6 | 9.4 | 112 | 9,210 | 156 | 63,020 | 124 | 40,858 | 19.4 | 121 |
| | 5/45 | 103 | 5 | | 122 | IV+ | 164 | 20 | 229.7 | 9.0 | 16.0 | 8.9 | 113 | 9,711 | 156 | 66,759 | 124 | 43,473 | 19.2 | 123 |
| | 8/50 | 109 | 5 | | -- | -- | 170 | 26 | 221.6 | 12.4 | 15.5 | 9.3 | 112 | 10,292 | 157 | 71,569 | 127 | 46,625 | 19.8 | 125 |
| | 8/55 | 114 | 5 | | 122 | IV+ | 164 | 25 | 247.1 | 13.1 | 16.6 | 9.8 | 116 | 10,765 | 154 | 74,975 | 126 | 49,445 | 20.2 | 127 |
| | 9/60 | 119 | 5 | | 120 | IV+ | 152 | 22 | 240.3 | 11.8 | 17.0 | 9.9 | 118 | 10,476 | 145 | 73,506 | 120 | 48,824 | 20.3 | 128 |
| 90 | 9/39 | 98 | | 1.000 | 154 | III+ | 138 | 33 | 285.0 | 43.9 | 19.5 | 15.6 | 146 | 14,756 | 131 | 110,751 | 123 | 77,908 | 22.0 | 152 |
| | 5/45 | 103 | 5 | | 156 | II- | 132 | 30 | 295.0 | 43.9 | 20.3 | -- | 149 | 15,463 | 125 | 116,951 | 119 | 83,577 | 22.4 | 155 |
| | 8/50 | 109 | 6 | | 157 | II- | 133 | 30 | 309.5 | 44.1 | 20.7 | -- | 150 | 16,518 | 125 | 123,668 | 118 | 88,811 | 24.1 | 159 |
| | 5/56 | 114 | 5 | | 159 | II- | 122 | 32 | 304.9 | 49.9 | 21.1 | 16.9 | 155 | 16,470 | 115 | 128,082 | 110 | 93,475 | 25.9 | 162 |
| | 9/60 | 119 | 5 | | 156 | II- | 118 | 31 | 306.7 | 46.8 | 21.8 | 16.6 | 158 | 16,869 | 108 | 129,648 | 105 | 95,653 | 25.4 | 166 |

[1/] 1956 values for plots 4, 5, and 90 were revised in 1960. All other values for 1956 and prior are taken from the 1956 office report.

[2/] Area reduced for portion of plot included in adjacent area clear cut about 1953.

## OLYMPIC PLOTS 1 to 4

Plots 1 and 2 are adjacent to U. S. Highway 101, about 3 miles south of Quilcene, Wash. Plots 3 and 4 are about 5 miles south of Blyn, on the Jimmiecomelately Creek road.

Back in the Prohibition Era while plot 4 was being established by Walter Meyer and his helpers, a local bootlegger, who had two 50-gallon stills within 100 feet, was on tenterhooks, not knowing whether to hover around or to get clear out of the country.

Poria weirii root rot has killed many trees on all of the plots since 1941 and on plot 3 is responsible, together with considerable wind and ice storm damage, for steadily decreasing plot values relative to normal values.

Stem maps are available for Olympic plots 1 and 2.

Plot 1 – At age 51; showing largest tree on plot (1926).

Plot 3 – At age 42; nearly normal stocking is evident (1926).

# Table 5.--Olympic permanent sample plots 1, 2, 3, and 4; statistics of the live stand (values on horizontal acre basis)

| Plot No. | Month and year measured | Age, years | Growth period, years | Horizontal area, acres | Site index, feet | Site quality | Stand 2.6 inches and more in d.b.h. | | | | | | | | Conifer stand | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Number of trees | | Basal area, square feet | | Average d.b.h., inches | | Average height of conifers, feet | Volume of conifers, cubic feet | 6.6+ inches d.b.h. | | 11.6+ inches d.b.h. | | Dominants and codominants | |
| | | | | | | | Conifers | Hardwoods | Conifers | Hardwoods | Conifers | Hardwoods | | | Number of trees | Volume, board feet (International ¼-inch rule) | Number of trees | Volume, board feet (Scribner rule) | Average d.b.h., inches | Average height, feet |
| 1 | 9/26 | 51 | | 1.00 | 130 | III- | 411 | 33 | 185.7 | 5.32 | 9.1 | 5.4 | 76 | 6,265 | 252 | 34,100 | 88 | 14,460 | 13.2 | 92 |
| | 9/31 | 56 | 5 | | 132 | III- | 377 | 23 | 198.2 | 4.99 | 9.8 | 6.3 | 80 | 6,945 | 256 | 39,990 | 98 | 18,640 | 13.6 | 99 |
| | 9/36 | 61 | 5 | | 130 | III- | 347 | 18 | 210.2 | 4.48 | 10.6 | 6.8 | 85 | 7,725 | 254 | 47,300 | 104 | 23,260 | 14.4 | 102 |
| | 9/41 | 66 | 5 | | 126 | III- | 307 | 11 | 221.4 | 3.42 | 11.3 | 7.6 | 89 | 8,194 | 250 | 50,161 | 112 | 25,976 | 15.3 | 103 |
| | 12/46 | 71 | 5 | | 125 | III- | 282 | 9 | 228.1 | 2.30 | 12.2 | 6.8 | 94 | 8,726 | 239 | 55,457 | 117 | 30,382 | 15.8 | 106 |
| | 4/57 | 81 | 10 | | 130 | III- | 273 | 5 | 257.4 | 1.64 | 13.1 | 7.8 | 103 | 10,544 | 227 | 70,141 | 129 | 42,049 | 17.1 | 118 |
| 2 | 9/26 | 51 | | 1.00 | 130 | III- | 389 | 14 | 176.3 | 1.71 | 9.1 | 4.7 | 74 | 5,925 | 271 | 32,190 | 57 | 10,590 | 12.9 | 92 |
| | 9/31 | 56 | 5 | | 133 | III- | 349 | 8 | 181.1 | 1.17 | 9.8 | 5.2 | 84 | 6,585 | 271 | 39,480 | 72 | 14 370 | 12.9 | 100 |
| | 9/36 | 61 | 5 | | 136 | III | 334 | 7 | 193.3 | 1.00 | 10.3 | 5.1 | 91 | 7,325 | 266 | 44,970 | 89 | 19,180 | 13.7 | 107 |
| | 9/41 | 66 | 5 | | 134 | III- | 295 | 4 | 198.3 | .43 | 11.1 | 4.4 | 95 | 7,710 | 253 | 48,574 | 102 | 22,601 | 14.4 | 110 |
| | 12/46 | 71 | 5 | | 130 | III- | 274 | 5 | 205.8 | .81 | 11.7 | 5.5 | 99 | 8,142 | 248 | 52,725 | 109 | 26,521 | 14.6 | 111 |
| | 4/57 | 81 | 10 | | 128 | III- | 249 | 3 | 220.8 | .62 | 12.8 | 6.1 | 104 | 9,292 | 222 | 62,023 | 120 | 36,289 | 15.7 | 116 |
| 3 | 10/26 | 42 | | .75 | 127 | III- | 611 | 103 | 148.7 | 13.54 | 6.7 | 4.9 | 67 | 4,440 | 244 | 17,880 | 19 | 1,970 | 9.6 | 79 |
| | 9/31 | 47 | 5 | | 125 | III- | 563 | 92 | 155.6 | 15.96 | 7.1 | 5.6 | 73 | 5,125 | 265 | 23,140 | 33 | 4,000 | 9.9 | 84 |
| | 9/36 | 52 | 5 | | 120 | IV+ | 508 | 49 | 169.0 | 8.60 | 7.8 | 5.7 | 75 | 5,475 | 275 | 26,920 | 47 | 6,980 | 10.7 | 86 |
| | 9/41 | 57 | 5 | | 122 | IV+ | 457 | 41 | 176.8 | 8.35 | 8.4 | 6.1 | 79 | 6,320 | 284 | 33,132 | 64 | 9,913 | 11.3 | 92 |
| | 12/46 | 62 | 5 | | 119 | IV+ | 385 | 27 | 171.8 | 8.10 | 9.0 | 7.5 | 84 | 6,242 | 263 | 35,032 | 68 | 11,689 | 11.8 | 94 |
| | 4/57 | 72 | 10 | | 118 | IV+ | 324 | 20 | 182.5 | 8.82 | 10.2 | 9.0 | 92 | 7,070 | 252 | 42,501 | 87 | 17,351 | 13.2 | 101 |
| 4 | 10/26 | 42 | | .75 | 126 | III- | 929 | 15 | 191.6 | 2.69 | 6.1 | 5.7 | 68 | 5,920 | 289 | 19,650 | 8 | 980 | 9.0 | 78 |
| | 9/31 | 47 | 5 | | 125 | III- | 732 | 16 | 192.4 | 2.99 | 6.9 | 5.9 | 74 | 6,370 | 331 | 25,780 | 19 | 2,340 | 9.4 | 84 |
| | 9/36 | 52 | 5 | | 123 | IV+ | 633 | 12 | 199.9 | 2.63 | 7.6 | 6.3 | 77 | 6,803 | 346 | 32,719 | 37 | 5,443 | 10.2 | 88 |
| | 9/41 | 57 | 5 | | 122 | IV+ | 547 | 12 | 206.0 | 2.39 | 8.3 | 6.0 | 83 | 7,466 | 341 | 38,613 | 64 | 9,905 | 10.8 | 92 |
| | 12/46 | 62 | 5 | | 119 | IV+ | 464 | 12 | 207.0 | 2.52 | 9.0 | 6.2 | 87 | 7,683 | 337 | 42,977 | 79 | 13,105 | 11.5 | 96 |
| | 4/57 | 72 | 10 | | 116 | IV- | 397 | 4 | 227.0 | 1.68 | 10.3 | 8.8 | 92 | 8,780 | 324 | 50,475 | 99 | 20,245 | 12.3 | 99 |

## GIFFORD PINCHOT PLOTS

### 1 to 5, 7, and 9

These plots lie in two groups: plots 1 to 5 in the Cispus River drainage, 10-1/2 miles southeast of Randle, Wash., and plots 7 and 9 on the Kiona Peak trail about 3 miles northwest of Randle.

The Cispus River group provides a striking, and aesthetically pleasing, example of the maximum yields attainable in natural stands. At the last measurement (average age 83 years, and site index 177), they averaged 90,211 board feet, Scribner rule, per acre.

All of these plots were stem-mapped at establishment.

Plot 3 – At age 50 (1927).

Plot 7 – A magnificent stand underway at age 50 (1927).

# Table 6.--Gifford Pinchot permanent sample plots 1-5 (Camp Creek), 7 and 9 (Kiona Peak); statistics of the live stand (values on horizontal acre basis)

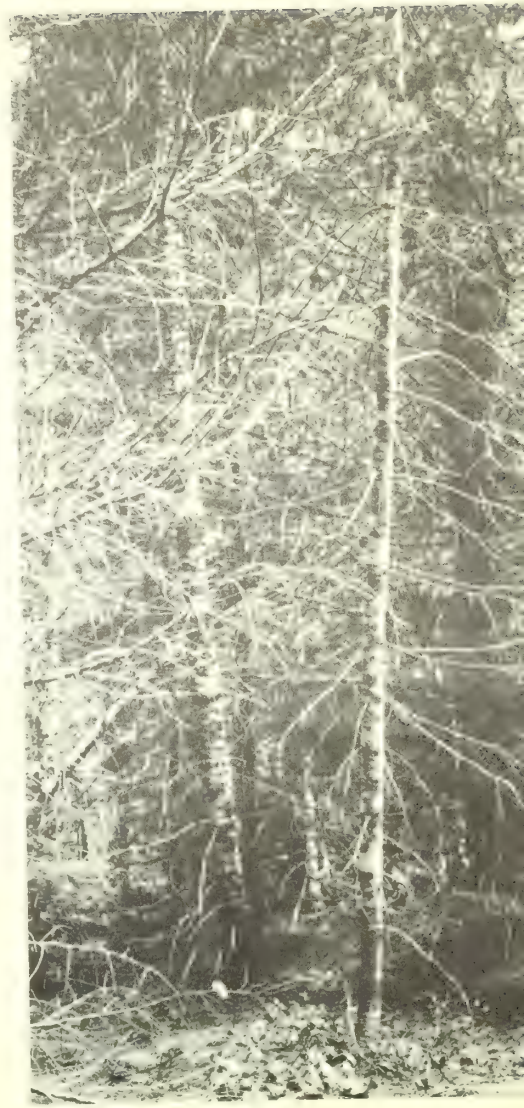
| Plot No. | Month and year measured | Age, years | Growth period, years | Horizontal area, acres | Site index, feet | Site quality | Stand 2.6 inches and more in d.b.h. | | | | | | | | Conifer stand | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Number of trees | | Basal area, square feet | | Average d.b.h., inches | | Average height of conifers, feet | Volume of conifers, cubic feet | 6.6+ inches d.b.h. | | 11.6+ inches d.b.h. | | Dominants and codominants | |
| | | | | | | | Conifers | Hardwoods | Conifers | Hardwoods | Conifers | Hardwoods | | | Number of trees | Volume, board feet (International ¼-inch rule) | Number of trees | Volume, board feet (Scribner rule) | Average d.b.h., inches | Average height, feet |
| Camp Creek | | | | | | | | | | | | | | | | | | | | |
| 1 | 4/27 | 50 | | 1.00 | 179 | II+ | 227 | 0 | 255.8 | -- | 14.4 | -- | 117 | 10,800 | 224 | 74,330 | 156 | 44,650 | 17.5 | 125 |
| | 5/32 | 55 | 5 | | 176 | II+ | 205 | 0 | 271.3 | -- | 15.6 | -- | 124 | 12,490 | 204 | 88,140 | 154 | 56,270 | 18.2 | 130 |
| | 4/37 | 60 | 5 | | 179 | II+ | 180 | 0 | 286.1 | -- | 17.1 | -- | 133 | 13,900 | 180 | 101,700 | 158 | 67,900 | 19.2 | 139 |
| | 5/43 | 66 | 6 | | 172 | II | 164 | 0 | 297.5 | -- | 18.2 | -- | 143 | 15,375 | 164 | 113,770 | 152 | 77,830 | 20.8 | 148 |
| | 11/52 | 76 | 10 | | 177 | II+ | 150 | 0 | 322.4 | -- | 19.9 | -- | 159 | 19,405 | 150 | 140,841 | 146 | 100,742 | 21.8 | 163 |
| | 9/57 | 81 | 5 | | 181 | II+ | 140 | 0 | 326.0 | -- | 20.7 | -- | 160 | 18,629 | 140 | 143,074 | 137 | 103,412 | 22.9 | 166 |
| 2 | 4/27 | 50 | | 1.00 | 156 | II- | 295 | 0 | 223.7 | -- | 11.8 | -- | 95 | 8,520 | 263 | 55,200 | 120 | 27,900 | 16.1 | 109 |
| | 5/32 | 55 | 5 | | 160 | II- | 282 | 0 | 246.4 | -- | 12.7 | -- | 106 | 10,080 | 258 | 66,920 | 130 | 37,350 | 17.0 | 118 |
| | 4/37 | 60 | 5 | | 158 | II- | 236 | 0 | 258.3 | -- | 14.2 | -- | 114 | 10,920 | 228 | 73,750 | 138 | 44,430 | 18.2 | 122 |
| | 6/43 | 66 | 6 | | 166 | II | 192 | 0 | 266.7 | -- | 16.0 | -- | 136 | 12,605 | 192 | 90,491 | 141 | 57,831 | 19.3 | 138 |
| | 11/52 | 76 | 10 | | 166 | II | 172 | 0 | 290.5 | -- | 17.6 | -- | 143 | 15,110 | 172 | 112,259 | 138 | 75,078 | 20.3 | 151 |
| | 9/57 | 81 | 5 | | 175 | II | 163 | 0 | 302.1 | -- | 18.4 | -- | 150 | 16,325 | 163 | 122,554 | 135 | 84,344 | 21.3 | 159 |
| 3 | 4/27 | 50 | | 1.00 | 168 | II | 256 | 0 | 243.7 | -- | 13.2 | -- | 109 | 10,180 | 253 | 68,000 | 142 | 36,920 | 16.6 | 117 |
| | 5/32 | 55 | 5 | | 164 | II- | 250 | 0 | 267.9 | -- | 14.0 | -- | 114 | 11,680 | 250 | 79,110 | 153 | 45,380 | 17.4 | 121 |
| | 4/37 | 60 | 5 | | 171 | II | 215 | 0 | 279.3 | -- | 15.4 | -- | 124 | 12,980 | 215 | 91,710 | 153 | 57,000 | 18.5 | 133 |
| | 5/43 | 66 | 6 | | 167 | II | 188 | 0 | 289.0 | -- | 16.8 | -- | 132 | 14,039 | 188 | 101,654 | 150 | 66,034 | 19.5 | 139 |
| | 11/52 | 76 | 10 | | 170 | II | 152 | 0 | 294.0 | -- | 18.8 | -- | 150 | 16,042 | 152 | 121,085 | 137 | 83,914 | 20.7 | 155 |
| | 9/57 | 81 | 5 | | 174 | II | 131 | 0 | 281.9 | -- | 19.9 | -- | 154 | 15,353 | 131 | 116,464 | 124 | 82,029 | 22.1 | 159 |
| 4 | 4/27 | 56 | | .75 | 155 | II- | 223 | 20 | 205.7 | 2.6 | 13.0 | 4.8 | 106 | 8,460 | 187 | 55,010 | 112 | 32,410 | 18.0 | 116 |
| | 5/32 | 61 | 5 | | 158 | II- | 207 | 20 | 222.4 | 3.0 | 14.0 | 5.3 | 113 | 9,590 | 181 | 65,000 | 115 | 39,900 | 18.6 | 124 |
| | 4/37 | 66 | 5 | | 166 | II | 191 | 20 | 242.1 | 3.7 | 15.2 | 5.8 | 124 | 11,110 | 173 | 79,040 | 113 | 50,190 | 19.8 | 136 |
| | 5/43 | 72 | 6 | | 161 | II- | 158 | 21 | 254.9 | 4.6 | 17.2 | 6.3 | 134 | 12,288 | 153 | 89,284 | 110 | 58,791 | 21.1 | 143 |
| | 11/52 | 82 | 10 | | 168 | II | 139 | 17 | 276.1 | 7.4 | 19.1 | 9.1 | 149 | 14,792 | 139 | 111,690 | 113 | 77,868 | 22.3 | 160 |
| | 9/57 | 87 | 5 | | 172 | II | 140 | 16 | 288.0 | 5.0 | 19.4 | 7.6 | 151 | 15,414 | 131 | 116,845 | 107 | 82,350 | 23.3 | 162 |
| 5 | 4/27 | 53 | | 1.00 | 163 | II- | 186 | 27 | 237.8 | 7.9 | 15.2 | 7.3 | 110 | 9,600 | 180 | 64,900 | 131 | 40,330 | 18.6 | 118 |
| | 5/32 | 57 | 4 | | 164 | II- | 180 | 23 | 248.2 | 7.4 | 15.9 | 7.7 | 118 | 10,770 | 176 | 75,060 | 133 | 47,170 | 18.8 | 124 |
| | 4/37 | 62 | 5 | | 171 | II | 164 | 12 | 263.7 | 5.1 | 17.2 | 8.8 | 130 | 12,380 | 162 | 88,720 | 131 | 58,880 | 20.0 | 136 |
| | 5/43 | 68 | 6 | | 167 | II | 138 | 9 | 275.2 | 4.7 | 19.1 | 9.8 | 138 | 13,389 | 138 | 98,286 | 125 | 67,292 | 21.9 | 144 |
| | 11/52 | 78 | 10 | | 182 | II- | 121 | 5 | 295.7 | 3.2 | 21.3 | 10.8 | 165 | 17,042 | 120 | 131,249 | 117 | 95,605 | 23.1 | 169 |
| | 9/57 | 83 | 5 | | 185 | II+ | 116 | 4 | 305.0 | 2.8 | 22.0 | 11.4 | 166 | 16,542 | 115 | 135,450 | 114 | 98,919 | 24.4 | 171 |
| Kiona Peak | | | | | | | | | | | | | | | | | | | | |
| 7 | 9/27 | 52 | | 1.00 | 171 | II | 257 | 15 | 212.2 | 9.1 | 12.3 | 10.6 | 110 | 9,220 | 234 | 62,820 | 133 | 33,470 | 16.5 | 125 |
| | 5/32 | 56 | 4 | | 170 | II | 245 | 13 | 230.2 | 8.5 | 13.1 | 11.0 | 115 | 10,370 | 224 | 71,600 | 141 | 40,550 | 16.6 | 127 |
| | 4/37 | 61 | 5 | | 171 | II | 216 | 11 | 238.8 | 7.3 | 14.2 | 11.1 | 124 | 11,270 | 200 | 80,340 | 142 | 48,490 | 17.9 | 134 |
| | 5/43 | 67 | 6 | | 171 | II | 213 | 2 | 260.9 | 1.4 | 15.0 | 11.5 | 130 | 13,177 | 188 | 95,164 | 145 | 60,772 | 19.6 | 146 |
| | 11/52 | 77 | 10 | | 176 | II+ | 192 | 0 | 286.9 | -- | 16.6 | -- | 147 | 15,901 | 173 | 119,216 | 141 | 80,872 | 21.7 | 163 |
| | 9/57 | 82 | 5 | | 179 | II+ | 178 | 0 | 294.4 | -- | 17.4 | -- | 150 | 15,786 | 163 | 123,389 | 138 | 85,339 | 21.6 | 164 |
| 9 | 9/27 | 58 | | 1.00 | 190 | III- | 413 | 3 | 222.2 | .3 | 9.9 | 4.1 | 83 | 7,940 | 261 | 46,550 | 113 | 22,810 | 16.1 | 99 |
| | 5/32 | 62 | 4 | | 187 | III- | 376 | 3 | 231.8 | .3 | 10.6 | 4.1 | 88 | 8,460 | 255 | 51,240 | 125 | 27,170 | 16.2 | 101 |
| | 4/37 | 67 | 5 | | 181 | III- | 329 | 1 | 237.7 | .2 | 11.7 | 6.0 | 96 | 9,460 | 249 | 60,430 | 133 | 35,080 | 16.2 | 105 |
| | 5/43 | 73 | 6 | | 186 | III | 306 | 1 | 266.5 | .2 | 12.5 | 6.3 | 102 | 10,982 | 245 | 67,186 | 140 | 38,905 | 17.2 | 107 |
| | 11/52 | 83 | 10 | | 190 | III- | 282 | 1 | 280.1 | .2 | 13.7 | 6.3 | 110 | 12,176 | 234 | 83,044 | 151 | 49,956 | 17.8 | 112 |
| | 9/57 | 88 | 5 | | 187 | III | 266 | 1 | 289.8 | .2 | 14.4 | 6.3 | 116 | 13,001 | 226 | 90,270 | 149 | 54,134 | 18.6 | 116 |

## SNOQUALMIE PLOTS 1 and 2

These plots are on Skate Creek about 4 miles south of Longmire, Wash. Having only about 60 percent of the normal number of trees at establishment, they were chosen to contrast with the denser Gifford Pinchot plots. It is interesting to observe that, on a Scribner volume basis, the Snoqualmie plots were 408 and 291 percent of normal in 1928, and in 1957 they were 127 and 95 percent of normal, respectively.

Plot 1 – In 1928.

The openness of these plots contrasts well with the denser Gifford Pinchot plots.



Plot 2 – In 1928.

## Table 7.--Snoqualmie permanent sample plots 1 and 2, Skate Creek; statistics of the live stand (values on horizontal acre basis)

| Plot No. | Month and year measured | Age, years | Growth period, years | Horizontal area, acres | Site index, feet | Site quality | Stand 2.6 inches and more in d.b.h. | | | | | | | | Conifer stand | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Number of trees | | Basal area, square feet | | Average d.b.h., inches | | Average height of conifers, feet | Volume of conifers, cubic feet | 6.6+ inches d.b.h. | | 11.6+ inches d.b.h. | | Dominants and codominants | |
| | | | | | | | Conifers | Hardwoods | Conifers | Hardwoods | Conifers | Hardwoods | | | Number of trees | Volume, board feet (International ¼-inch rule) | Number of trees | Volume, board feet (Scribner rule) | Average d.b.h., inches | Average height, feet |
| 1 | 5/28 | 42 | | 0.50 | 130 | III | 388 | 6 | 182.7 | 2.2 | 9.3 | 8.3 | 72 | 5,140 | 214 | 27,590 | 92 | 13,890 | 14.2 | 81 |
| | 5/32 | 46 | 4 | | 128 | III | 374 | 6 | 205.4 | 2.2 | 10.0 | 8.3 | 79 | 6,200 | 222 | 34,070 | 110 | 18,490 | 14.5 | 85 |
| | 4/37 | 51 | 5 | | 138 | III | 296 | 4 | 218.2 | 2.0 | 11.6 | 9.2 | 90 | 7,420 | 216 | 44,700 | 120 | 26,130 | 15.6 | 97 |
| | 6/43 | 57 | 6.5 | | 145 | III | 284 | 2 | 238.7 | 1.8 | 12.4 | 13.0 | 99 | 8,850 | 208 | 56,748 | 130 | 35,260 | 17.0 | 108 |
| | 10/52 | 67 | 9.5 | | 143 | III | 242 | 2 | 251.1 | 1.8 | 13.8 | 13.0 | 106 | 9,986 | 190 | 66,396 | 130 | 41,678 | 17.8 | 118 |
| | 8/57 | 72 | 5 | | [1/] 141 | III | 230 | 2 | 261.5 | 1.8 | 14.4 | 13.0 | [2/] 110 | 10,928 | 184 | 75,092 | 130 | 48,482 | 18.8 | 128 |
| 2 | 5/28 | 42 | | .75 | 137 | III | 318 | 0 | 167.3 | -- | 9.8 | -- | 74 | 5,010 | 160 | 26,950 | 79 | 14,560 | 15.5 | 85 |
| | 5/32 | 46 | 4 | | 133 | III | 313 | 0 | 185.6 | -- | 10.4 | -- | 79 | 5,780 | 169 | 32,970 | 91 | 18,780 | 15.9 | 88 |
| | 4/37 | 51 | 5 | | 142 | III | 257 | 0 | 198.7 | -- | 11.9 | -- | 91 | 6,760 | 161 | 41,500 | 102 | 25,310 | 16.8 | 100 |
| | 6/43 | 57 | 6.5 | | 149 | III | 239 | 0 | 218.0 | -- | 12.9 | -- | 102 | 8,097 | 162 | 52,768 | 113 | 33,474 | 17.9 | 112 |
| | 10/52 | 67 | 9.5 | | 154 | III+ | 216 | 0 | 234.3 | -- | 14.1 | -- | 106 | 9,564 | 153 | 65,313 | 109 | 42,507 | 19.1 | 127 |
| | 8/57 | 72 | 5 | | [1/] 156 | II- | 208 | 0 | 237.2 | -- | 14.5 | -- | [2/] 112 | 10,166 | 149 | 71,571 | 104 | 47,313 | 20.1 | 136 |

[1/] Determined in 1957 by using average height of the dominants and codominants measured for height. Applied to curves in Bulletin 201.

[2/] Smaller sample of trees used for construction of height curve in 1957.

## MOUNT HOOD PLOTS 1, 2, and 3

Located on the Devils Peak Way Trail near Rhododendron, Oreg., these plots were established to compare the development of stands of different densities. On the basis of average diameter, plots 1, 2, and 3 were 87, 111, and 101 percent of normal, respectively. This comparison has been thwarted by severe wind damage to plot 1, which lies on an exposed slope. On the basis of age and site index, all plots were considerably understocked, in number of trees, in 1930. It was thought to be extraordinary, then, that they should have Scribner volumes so much in excess of normal (221, 217, and 174 percent). We know now, of course, that below-normal stocking in number of trees is often associated with above-normal board-foot volume.

Plot 1 – In 1930.

Plot 2 – In 1930.

## Table 8.--Mount Hood permanent sample plots 1, 2, and 3; statistics of the live stand (values on horizontal acre basis)

| Plot No. | Month and year measured | Age, years | Growth period, years | Horizontal area, acres | Site index, feet | Site quality | Stand 2.6 inches and more in d.b.h.[1/] | | | | | | | | Stand 6.6+ inches d.b.h. | | | Stand 11.6+ inches d.b.h. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Number of trees | | Basal area, square feet | | Average d.b.h., inches | | Average height of conifers, feet | Volume of conifers, cubic feet | Number of trees | | Volume of conifers, board feet (International ¼-inch rule) | Number of trees | | Volume of conifers, board feet (Scribner rule) |
| | | | | | | | Conifers | Hardwoods | Conifers | Hardwoods | Conifers | Hardwoods | | | Conifers | Hardwoods | | Conifers | Hardwoods | |
| 1 | 4/30 | 45 | | 1.0 | 132 | III- | 344 | 20 | 172.2 | 3.4 | 9.6 | 5.6 | 77 | 5,798 | 234 | 5 | 31,936 | 95 | 0 | 13,267 |
| | 10/34 | 50 | 5 | | 132 | III- | 306 | 20 | 183.9 | 4.2 | 10.5 | 6.2 | 85 | 6,659 | 228 | 7 | 39,326 | 111 | 0 | 19,271 |
| | 9/39 | 55 | 5 | | 133 | III- | 249 | 20 | 185.1 | 4.6 | 11.7 | 6.5 | 90 | 6,968 | 207 | 7 | 43,550 | 116 | 0 | 23,414 |
| | 3/45 | 60 | 5 | | 134 | III- | 211 | 19 | 193.6 | 4.6 | 13.0 | 6.7 | 100 | 7,635 | 195 | 7 | 49,706 | 123 | 0 | 28,136 |
| | 5/52 | 67 | 7 | | -- | -- | 187 | 19 | 205.7 | 5.0 | 14.2 | 7.0 | 112 | 8,417 | 178 | 8 | 56,207 | 128 | 1 | 34,028 |
| 2 | 4/30 | 45 | | 1.0 | 124 | IV+ | 464 | 29 | 220.8 | 6.0 | 9.3 | 6.2 | 77 | 7,144 | 380 | 10 | 37,717 | 78 | 0 | 9,755 |
| | 10/34 | 50 | 5 | | 124 | IV+ | 416 | 27 | 232.8 | 6.4 | 10.1 | 6.6 | 83 | 8,165 | 370 | 11 | 47,395 | 112 | 1 | 16,866 |
| | 9/39 | 55 | 5 | | 128 | III- | 368 | 21 | 242.2 | 4.3 | 11.0 | 6.2 | 88 | 8,811 | 347 | 9 | 53,455 | 131 | 0 | 22,673 |
| | 3/45 | 60 | 5 | | 129 | III- | 325 | 22 | 248.9 | 6.4 | 11.9 | 7.3 | 95 | 9,657 | 310 | 12 | 61,267 | 159 | 1 | 30,232 |
| | 5/52 | 67 | 7 | | -- | -- | 305 | 20 | 263.3 | 6.1 | 12.6 | 7.5 | 101 | 10,607 | 293 | 10 | 68,952 | 164 | 2 | 35,894 |
| 3 | 4/30 | 45 | | 1.0 | 124 | IV+ | 417 | 64 | 200.3 | 14.6 | 9.4 | 6.5 | 77 | 6,709 | 300 | 21 | 32,543 | 81 | 1 | 11,301 |
| | 10/34 | 50 | 5 | | 124 | IV+ | 383 | 56 | 210.2 | 15.4 | 10.0 | 7.1 | 83 | 7,449 | 300 | 24 | 43,236 | 101 | 2 | 17,142 |
| | 9/39 | 55 | 5 | | 135 | III | 325 | 43 | 218.1 | 13.7 | 11.1 | 7.6 | 92 | 8,261 | 278 | 24 | 51,370 | 123 | 2 | 23,390 |
| | 3/45 | 60 | 5 | | 139 | III | 295 | 33 | 230.3 | 11.8 | 12.0 | 8.1 | 100 | 9,355 | 257 | 21 | 60,873 | 137 | 2 | 31,347 |
| | 5/52 | 67 | 7 | | -- | -- | 281 | 22 | 247.5 | 9.1 | 12.7 | 8.7 | 106 | 10,358 | 246 | 15 | 69,545 | 149 | 2 | 38,913 |

[1/] For 1930, 1934, and 1939, trees 0.5 inch and more in d.b.h. were included.

## KNOWLEDGE GAINED FROM PERMANENT GROWTH AND YIELD PLOTS

To the best of the author's knowledge, all published information derived from the plots is summarized in the following section. No attempt has been made to cover publications other than those based on direct analysis of plot data.

The articles are discussed by subject matter, chronologically within each subject. Remarks are confined to the main ideas in each article.

### NORMAL YIELD TABLES

Probably the most significant publication to which these plots contributed data is Technical Bulletin 201, "The Yield of Douglas-fir in the Pacific Northwest" (McArdle et al., 1949), which includes Bruce's "A Revised Yield Table for Douglas-fir" (1948). This has been a standard reference of foresters since its publication. Subsequent data obtained from the growth and yield plots have generally substantiated the yield tables.

### TRENDS TOWARD NORMALITY

Meyer (1933) pioneered work in this direction for Douglas-fir. The permanent sample plots had not been established long enough to allow consideration of the effect of age, but he was able to demonstrate the effect of existing normality percentage on future normality and derived regression equations for the standard units of measure according to the form:

$$\text{change } (\%) = a + b \text{ (present normality)}.$$

Briegleb, in a later analysis (1942) was able to use age as another independent variable. His regression equations of the form,

$$\text{change } (\%) = a + b \text{ (age)} + c \text{ (normality)},$$

provided multiple correlation coefficients above 0.6 (43 degrees of freedom) for cubic-foot, International board-foot, and Scribner board-foot standards of normality.

### GROWTH OF DOUGLAS-FIR

Reporting of growth data from permanent sample plots in Douglas-fir stands began with a presentation by Munger (1915) at the annual meeting of the Society of American Foresters. The Willamette plots had then been established for 5 years.

Meyer (1928) reported further on the growth of these plots and observed how distribution of stand diameter class frequency changed with time. He noted that all plots showed a trend in frequency distribution from a skewness toward the small diameters in young stands, through a nearly normal distribution, to a skewness toward the larger diameters as the stands matured. A thorough discussion of diameter distribution series in even-aged stands became available in a subsequent publication (Meyer, 1930).

Munger (1946b) had the opportunity to review the Willamette plots after 35 consecutive years of experience with them. A most valuable contribution of these plots has been a detailed life history typical of stands occurring over millions of acres in the Pacific Northwest. Although they had suffered occasional heavy losses from fire, insects,

snowbreak, and wind, they had an average volume per acre of over 78,000 board feet, Scribner rule, at age 90, thus demonstrating the recuperative powers of natural stands. Despite periodic annual volume growth ranging from 286 to minus 99 cubic feet per acre, the plots have substantiated the generalization that the various measures of stocking for a particular stand all trend toward normality.

The Douglas-fir Second-Growth Management Committee (1947) analyzed 25,000 individual tree measurements, covering 35 years' experience with the permanent growth and yield plots, to develop stand table projection methods for well-stocked Douglas-fir stands. This analysis derived diameter growth and Scribner and cubic-volume growth according to site index, crown class, d.b.h., and stand age. The tables in the reference were for site III only and illustrated the following general conclusions in regard to cubic-volume growth:

1. When trees of a certain d.b.h. but of differing ages and crown classes are considered, growth and growth percent decrease with increasing age and increase with increasing dominance.

2. When trees of a certain age and crown class are considered, growth increases with d.b.h. Growth percent, however, decreases with increasing size, except for the older age classes where there is little differentiation.

Over all site classes, a study such as this provides an unexcelled view of the growth dynamics of natural, even-aged, well-stocked stands of Douglas-fir.

Spurr (1952), in assessing various stand characteristics as direct estimators of cubic volume per acre, bypassed tree volume tables and used the plot data to make regression analyses of volume on different combinations of basal area, total height (dominants and codominants), age, site index, and basal area times height. Basal area, total height, and the product of these two provided the most accurate estimates; age and site index, the least accurate. Further, the height times basal area estimate alone gave a standard error of 6 percent.

He also analyzed the plot data to test rate of cubic-volume growth against several stand characteristics. Site index and stand age had the highest correlation with volume growth. The correlation coefficient was 0.765 (33 degrees of freedom). Average diameter of the stand made a slight improvement in the estimate.

In a discussion of trends of basal area per acre with stand age, Spurr used the permanent plot data to show the linearity of gross basal area with time. The curvilinear trend of net basal area reflected the increasing significance of mortality as stands get older.

A linear regression analysis of eight factors related to net basal area growth showed that basal area itself is the best single indicator. The addition of age as an independent variable improved the correlation somewhat but, for all practical purposes, basal area alone was suitable.

Staebler (1954) used data from some of the 78-year-old Gifford Pinchot plots as an argument to retain thrifty young stands at least to the culmination of mean annual increment. The average annual value growth percent of 9.9, achieved by these plots in going from 52 to 78 years old, might be considered adequate by any owner. Furthermore, mean annual increment and value per thousand board feet were still increasing.

Johnson (1955) used the plot remeasurements to compare the accuracy of seven common methods for volume growth prediction. The best method assumed that

well-stocked stands put on normal growth. The other methods gave biased results or had a larger standard deviation than did the normal-growth method. This confirms Spurr's conclusions, noted previously, in regard to cubic-volume growth.

Worthington and Staebler (1961), in examining some of the permanent sample plots, found that trees below the average diameter of the stands had 27 percent of the total basal area, though they contributed only 16 percent of the total basal-area growth. The implication was that thinnings could remove about 25 percent of stand basal area in the smaller trees with little sacrifice in increment.

The same authors also found a definite relation between crown class and the live crown–total height ratio. The ratio increases with dominance.

## MORTALITY

Johnson (1953) examined the permanent plot records for mortality. He found that the mortality on all plots averaged 83 cubic feet or 284 board feet (Scribner) per acre per year, a figure significant enough to alert forest-land owners.

Staebler (1953) found that reasonable estimates of mortality for any particular diameter class in the permanent plot stands could be made on the basis of stand age, site index, and d.b.h. Separate equations were required, one for intermediate and suppressed trees and one for dominants and codominants. A strong correlation coefficient, 0.715 (68 degrees of freedom), for the intermediate-suppressed equation reflected the more regular mortality due to suppression in well-stocked stands. The dominant-codominant equation had a weak correlation coefficient, 0.266 (68 degrees of freedom), reflecting the irregular mortality in the dominant portion of stands.

## GROSS YIELD TABLES

Munger (1946a) wrote on the cumulative mortality and gross growth of these plots. His article was the first attempt to derive gross yield tables for Douglas-fir, but he felt that the data were too limited for his figures to be applicable over all site and age classes.

Staebler (1955a) expressed average volume of trees that die during any particular decade as a function of the average volume of trees living at the beginning of that decade. Limitations on age and size range of timber prohibited development of a curvilinear regression. Therefore, two linear regressions were combined to fit the data. This work led to Staebler's "Gross Yield and Mortality Tables for Fully Stocked Stands of Douglas-fir" (1955b). These gross yield figures provide a goal for forest managers.

## ESTIMATING STAND AGE

As used in McArdle's (1949) Douglas-fir yield tables, stand age was determined by averaging dominant and codominant trees in the ratio of 1 to 4. In analyzing the plot data, Johnson (1954) found that estimates of stand age, reliable enough for use with the yield tables, could be made from dominant-tree measurements only:

Subtract 1 year for dominants 30 to 80 years old

Subtract 2 years for dominants 81 to 130 years old

Subtract 3 years for dominants 131 to 180 years old

## HEIGHT GROWTH AND SITE INDEX

Staebler (1948) proposed measuring heights of only dominant trees for determination of site index. More reliable identification of dominants plus clearer visibility of their tops reduces both bias and measurement time in field work. He used data from the growth and yield plots to arrive at a factor for converting from height of dominants only to that of dominants and codominants.

Spurr (1952) felt that, in general, actual growth from permanent sample plots would develop better site index curves than harmonized data from temporary plots. He used the height and age measurements from the permanent plots to construct natural site index curves for Douglas-fir. A comparison of these curves with the yield table curves shows that the natural site curves have a shallower gradient in the younger age classes.

In Spurr's analysis of the plot data, age was found to be the single factor best related to height growth. With two factors, however, total height itself and site index had the best correlation. If site index of a stand is known, the need to find stand age in predicting height growth is eliminated. Otherwise, the correlations substantiate the general use of site index curves for height-growth prediction.

## LEVELS OF GROWING STOCK

Munger (1945) offered the accrued experience of permanent sample plot remeasurements as a guide to identifying and enumerating reserve trees under low-thinning practice.

Briegleb (1952) used data from the Wind River growth and yield plots plus other sources to substantiate two related hypotheses: (1) that, for trees of a given breast-high diameter, the shorter ones have larger crowns than the taller; and (2) that, for trees of a given height, those with greater breast-high diameter have the larger crowns.

An analysis of measurements from thinned stands in Prussia, Denmark, and western Washington yielded an equation estimating, for average diameter, the desirable number of trees in percent of normal as a function of stand height in percent of normal. Briegleb's article presents tabular solutions to the equation as a guide to thinning practice. One principal advantage of this approach is its consideration of stand history. For example, a 60-year-old stand that had never before been thinned would be differentiated from a similar stand reduced in stocking by repeated thinnings.

## ECOLOGY

Spilsbury and Smith (1947) used tree-measurement and ground-cover observations on the growth and yield plots, as well as on numerous other areas, in their pioneering work on using ground-cover species as indicators of Douglas-fir site quality. In the United States, they were concerned primarily with the humid temperate areas on the west slopes of the Coast Ranges and of the Cascade Mountains. They established definite vegetational trends by site types. The key to site quality was not the presence or absence of certain species, but rather the relative dominance of certain species in relation to others. For instance, while salal may be abundant over all sites, it is dominant in the ground cover only on the poorer sites.

## FUTURE PLOT MANAGEMENT AND DISPOSITION OF DATA

Due to the shift in silvicultural emphasis from unmanaged to managed stands, the Pacific Northwest Forest and Range Experiment Station is shifting some of its responsibility for future remeasurement and maintenance of these plots.

The University of Washington has agreed to take over the maintenance and remeasurement of the plots located in the State of Washington. Copies of all remeasurement data will be furnished to the Experiment Station.

### DISPOSITION OF EXISTING DATA

Office reports will continue to be on file and available to the public at the Pacific Northwest Forest and Range Experiement Station in Portland, Oreg.

In addition to the tables presented here, these reports include tables of periodic and mean annual increment, periodic mortality, and relationship of plot values to normal stand values.

Basic individual tree data is being punched on data-processing cards so that this wealth of tree-growth information can be made available to all Northwest forest research agencies for a wide variety of future analyses. Scientists interested in using this data should write the Director of the Pacific Northwest Forest and Range Experiment Station for information on availability and use of a set of cards.

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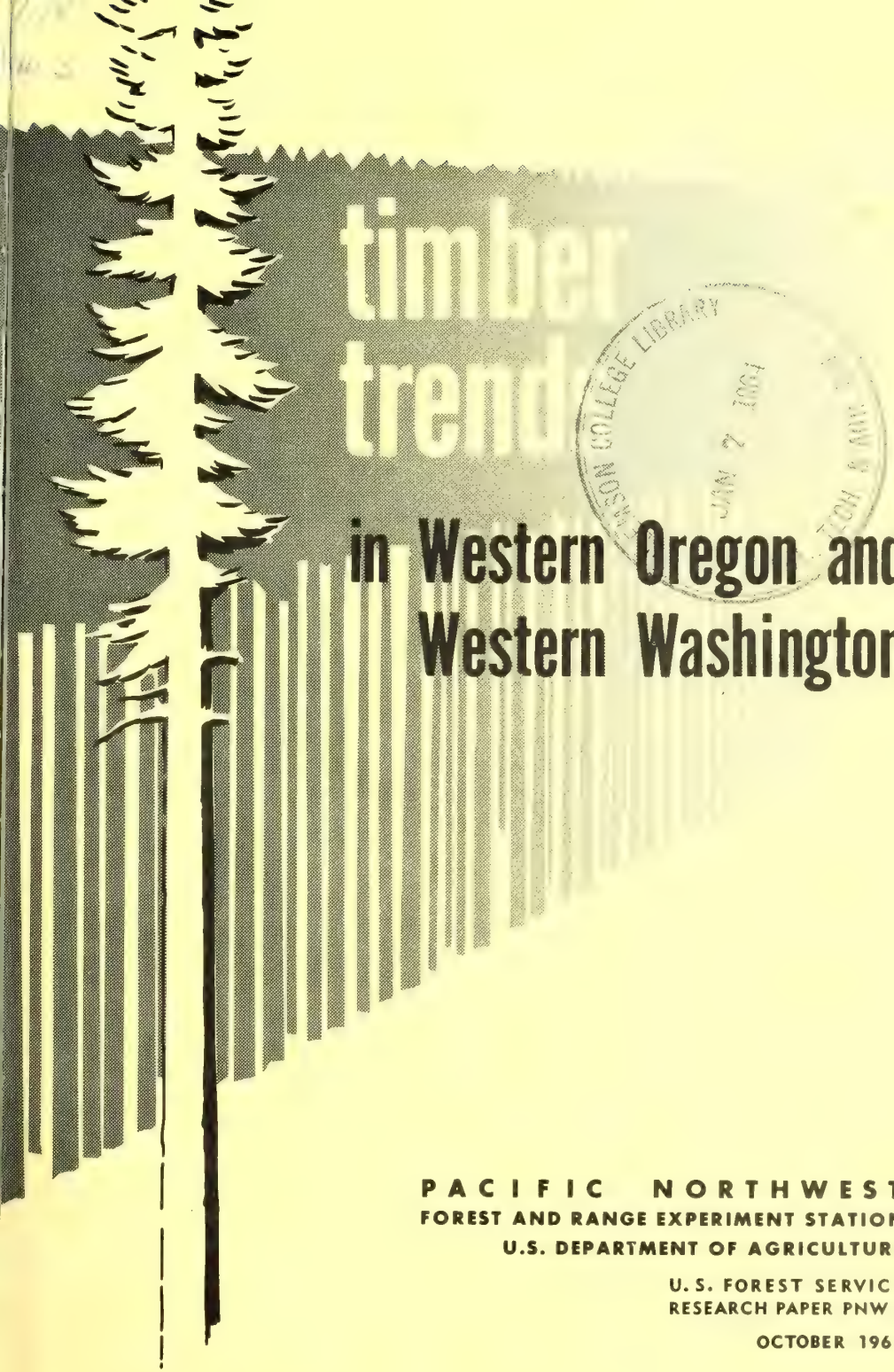

# timber trends in Western Oregon and Western Washington

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# TIMBER TRENDS IN WESTERN OREGON AND WESTERN WASHINGTON

by

Division of Forest Economics Research

PACIFIC NORTHWEST

FOREST AND RANGE EXPERIMENT STATION

Philip A. Briegleb, Director Portland, Oregon

FOREST SERVICE U. S. DEPARTMENT OF AGRICULTURE

# FOREWORD

This study of timber trends in the Douglas-fir region was undertaken in response to increasing public concern over the situation and outlook in the Pacific Northwest forest economy. Its objective is a long-term appraisal of timber supplies in the Douglas-fir subregion of western Oregon and Washington. The appraisal is made by examining the outlook for supplies of timber available from each of the major groups of ownership. Recognition is given to the effect of economic and technical factors such as the level and objectives of management, economic influences bearing on different classes of forest owners, present forest conditions, cutting practices, and potential productivity of the forest lands of the region.

The entire staff of the Division of Forest Economics Research participated in the very considerable tasks of formulating a basis for analyzing the supply situation, contacting public and private landowners and managers, and projecting the complex forest resource into the future. The authors of the study were able to draw freely from the most recent Forest Survey inventory information—detailed information which had not previously been analyzed.

The Forest Service has made numerous appraisals of the national timber supply situation in the past, but there have been relatively few analyses of regional situations. This one is unique in that it analyzes in depth the economic factors expected to control or influence timber supply in various classes of ownership. This has been done by building an economic model for explaining and estimating timber output in the region.

The model used in this study is concerned primarily with the long-range level of output that might be expected under the long-term influence of various economic forces. Short-run considerations such as impacts on prices and profits of alternative cutting policies have not been included in this analysis. Also, the study assumes economic objectives for Federal and other public forest ownerships comparable to those of private owners. In practice, it may be desirable to temper local objectives by broader considerations such as the impacts of Federal cutting and management policies on the total level of employment and on the stability of economic activity in the region.

Various assumptions have of necessity been made in developing estimates of rotation age, for example, and estimates of prospective timber output on various classes of ownership, including assumptions as to the appropriate guiding rates of interest for different owners, a highly elastic demand for timber products, and a long-range increase in prices for the young timber that is expected to be available in future years. While use of different assumptions for such items would result in somewhat different conclusions, it is believed that the model and the assumptions adopted in this study serve well the purpose of examining the de-

terminants of timber supply and the prospects for longrun timber supplies in the region.

The statements and conclusions in this report are not presented as direct recommendations for policy or program revisions, public or private. An attempt has of course been made to carry out this analysis within a framework of existing and anticipated factors, both economic and noneconomic, which must be taken into account in establishing goals and policies.

The outlook for timber supply in the Pacific Northwest is a timely and important subject. We believe that systematic studies of this sort will lead to improved understanding and to sounder decisions concerning the problems of managing our Nation's timber resources.

Carl A. Newport, Chief
Division of Forest Economics Research

# SUMMARY

The purpose of this study is to assess the influences upon timber output in the Douglas-fir subregion, the potential timber supply in the long run, and the problems of reaching the potential during the conversion of an old-growth to a young-growth timber economy.

An economic model is developed to account for the major factors influencing timber output. One factor is the management practices followed on the forest lands. Another is land use—the acreage and quality of land allocated to timber growing. The third influence upon output is bound up in the time element as expressed in the guiding rate of return on forest investments.

Management intensity is classed as intensive (or conservative, intermediate, and exploitive (or extensive). The study shows that the intensive or conservative owners tend to hold relatively large investments in growing stock and that such investments involve relatively low guiding rates of return, that is the rates of interest at which forest owners compound or discount values. On the other hand, exploitive-type owners make relatively small per acre investments and, in effect, have a high guiding rate of return. Determinants of guiding rates, such as availability of alternative investments, fringe benefits, risks and transfer costs, and characteristics of different owner classes, are indicated.

The economic model is used to demonstrate the considerable influence that the interest cost of building up or holding of growing stock has upon total output, primarily through its effect on length of rotation. Management costs and timber revenues are also examined with particular attention to the bearing of each determinant upon an owner's incentive to grow timber. The model demonstrates, for example, how lower conversion costs per unit of volume with advancing size and age of trees tend to influence rotation age. Other factors such as regeneration costs, quality differentials, timber value trends, and costs of timber stand improvements and fertilization also are analyzed in terms of impacts on rotation age and on the total output that may be expected from various types of owners.

In order that potential timber output in the region could be estimated, the influence of land use and land ownership also has been considered. Currently, 73 percent (25.8 million acres) of the 35 million acres of land in the Douglas-fir subregion is classed as commercial forest land, suitable and available for timber production. Under the land-use assumptions adopted in this study, this is reduced to 24.8 million acres by the year 2000. About half of this decrease of 1 million acres of commercial forest land is expected in public holdings and half in private. The reductions in each class of public holdings are expected to occur in proportion to the total amount in each. Both reductions and major shifts in ownership of commercial forest land are expected to take place in the three size classes of private holdings. Large holdings are assumed to increase from about 5.4 million

acres to 8.8 million. Medium-size holdings are assumed to drop from 1.7 million acres to 0.8 million. Small-size holdings are expected to drop from 6.1 million acres to 3.1 million.

After the various economic influences upon timber output and prospective land use are examined, estimates of the annual yields of timber that might economically be produced in the Douglas-fir subregion in the long run are next derived. For each class of owners, i.e., conservative, intermediate, or exploitive, guiding rates of return are assigned: 3, 6, and 12 percent, respectively. Economical per acre yields are estimated for each class of forest owner and for each forest type and site. The per acre yields estimated under the specified assumptions are then applied to the expected land use and forest ownership to estimate total annual yields in the long run.

As an illustration of the kinds of assumptions made in this analysis of the long run, take the case of the conservative owner of Douglas-fir site III land managed for continuous saw-log production. An even-aged silvicultural system is to be followed, with light intermediate cuttings beginning early enough in the life of each stand and continuing frequently enough to permit high utilization of the site. Harvest cuts are to be made at a rotation of close to 80 years, with an average breast-high diameter of crop trees of about 22 to 24 inches. After the final harvest cut, prompt regeneration of a good quality stand is to be assured by whatever means are necessary. The forest is to be managed under close professional supervision. It is to be provided with a road network, or equivalent means of access, to a high standard. All trees 6 inches and larger, d.b.h., are to be utilized to a 4-inch top; and losses from fire and other agencies will be held to a negligible level. Increases in unit value of wood are assumed to amount to 1 percent annually due to conversion and regeneration cost differentials. A prospective stumpage value of $40 (1957-59 basis) per thousand board feet, Scribner rule, is assumed.

On the basis of such calculations, it is estimated that the potential timber output of the Douglas-fir subregion in the long run amounts to an average of 526 board feet per acre, plus an additional 17 cubic feet per acre. The total saw log yield is estimated to be 13.1 billion board feet per year, plus 0.4 billion additional cubic feet per year. This is about 14 percent above the subregion's average annual timber output of 11.5 billion board feet during the decade of the 1950's. More than half of the total potential is attributed to type site 1 (chiefly Douglas-fir and ponderosa pine sites I and II). More than four-fifths is attributed to conservative owners, principally large-scale corporations and the Federal Government.

The effects of several alternative assumptions upon the longrun potential output also have been considered, including alternative price levels, interest rates, and land management and use. It is concluded, for example, that, within a rather wide range, stumpage price levels have but a rather small bearing upon the long-range output and the higher the price, the smaller the bearing of a given amount of price increase.

The guiding rate of interest works upon potential output through all the same influences as does price, and since it exerts an additional effect through its control over growing stock and rotation length, output is considerably more sensitive to the rate of interest than to the price level. Various ways of reducing guiding rates of interest, such as transfers of ownership, are indicated.

Consideration of alternative assumptions with regard to land use and management indicates that such changes as appear possible in the management of small holdings, for example, or the designation of additional public recreation areas would not alter significantly the estimate of long-range timber output in the region.

The longrun potential of 13.1 billion board feet plus 400 million cubic feet per year is in the nature of a destination or target. Since the end of the long run is distant, some may view the target with detachment or unconcern. But the means and the route for reaching the longrun level of production are of immense and immediate interest. Questions of timber yields during the transition period of conversion to a young-growth economy are therefore examined in the final chapter of the report.

Two important timber management tasks of the transition period are pointed out—scheduling the reduction of excess growing stock and achieving a desired distribution of age classes. The longrun estimate of required growing stock in the region under the specified management assumptions is some 203 billion board feet, or an average of 8,200 board feet per acre, Scribner rule, in trees 11 inches and larger in diameter to a minimum 8-inch top inside bark. The present total growing stock is about 647 billion board feet, or an average of about 25,000 board feet per acre to the same standard of measure. The degree of excess growing stock increases as one moves from the better to the poorer sites—largely because this is the general order in which the sites have been entered for exploitation and in which conversion to young growth has progressed.

The problem of distribution of growing stock by age classes is described by comparing the ideal age class acreage distribution with the actual. Stands less than 100 years old occupy 58 percent of the even-aged coniferous commercial forest land in the Douglas-fir subregion. On these lands, stands between 1 and 40 years are most prominent. About 20 percent of the region supports stands of 100 to 250 years, and 14 percent has stands over 250 years of age. Of this 8 percent of the area that is nonstocked, about half is in burns and old cutovers and half in recent cutovers.

To determine what changes are likely to occur in timber output and levels of growing stock if present trends in forest management and timber cutting should continue, detailed projections of timber growth and cut were made by decades to the year 2000 and thereafter to 2060. These projections indicate that the output or cut from all commercial forest lands of the subregion may average about 12.5 billion board feet annually during the 1960's and about 11.6 billion board

feet per year during the four decades 1960-2000. This would be essentially equal to the average of 11.5 billion board feet of annual cut in the decade of the 1950's. The character of the future timber output is expected to change as more of the harvest comes from smaller trees, thinnings, and lesser used species.

Finally, recognition is given to the possibility of modifying the outlook by intensifying forest management more rapidly than is now in prospect and by converting old-growth timber to young growth more rapidly than is now intended. There are many alternatives to the expected trends in output, depending upon cutting policies followed in old-growth stands and the nature and amount of investments in timber management. Accelerated reforestation activities and more rapid development of thinning and relogging, for example, could increase timber yields beyond those indicated in the projections. Accelerated cutting of old-growth timber also could lead to increases in total output of timber products, although at the risk of industrial instability in the region. Studies of such potential modifications of present trends must be the subject of future analyses that will supplement this initial study of the timber situation and outlook in the Douglas-fir subregion.

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# Chapter 1

## Introduction

The purpose of this report is to throw light on the future of timber growing and timber industry in western Oregon and western Washington. This part of the Pacific Northwest, the Douglas-fir subregion (fig. 1), has been the center of United States lumbering for several decades: Encompassing less than a twentieth of the Nation's forest land, the subregion has been responsible for as much as a fourth of the annual sawtimber harvest. Since World War II, it has become also a center of interest in timber management. Its transition from old-growth toward a young-growth timber economy is well underway.

### Questions on the Future

What is likely to be the yield of a young-growth timber economy? How will the yield be affected by competing uses of forest land, particularly recreation? How will it be affected by forest ownership, by timber-management policies and costs, and by timber prices? How will the young-growth yield compare with the vast outpouring of wood that abundant old growth has made possible? How severe will the adjustment be, from an old-growth to young-growth economy? What changes in quantity and quality of timber raw material must wood-using industry prepare for? How fast will the great supplies of Government old growth be liquidated, and what effect will the rate have upon the longrun timber supply? What bearing will public and private forest policies have upon the timber supply situation?

Such questions regarding the future are hard to resolve even though they relate to forests, ordinarily so resistant to time and innovation. Northwestern forests today are at the center of new and sharp changes. Along the western slopes of the Cascade Mountains, one may drive to timbering operations on ground that only the "day before yesterday" was untouched and unseen, a part of the timeless virgin wilderness. Foresters look to the possibility of tending and harvesting such tracts by air, a development that could place the timber under intensive management almost overnight. Before some areas are harvested, materials, manufacturing methods, and ways of life unknown today will greatly affect the timber value. Within a generation, the changes of a thousand years and more will come to bear on some of these forest lands.

Despite the uncertainties, it is judged useful to peer into the future. The course of forestry and wood industry has a direct, large influence on the well-being of nearly everyone in western Oregon and western Washington. Furthermore, the prospect for one of the Nation's chief wood-producing areas is clearly of national interest.

Figure 1.—Three districts of the Douglas-fir subregion of the Pacific Northwest.

Any study of the future must be rooted in the past. The historical foundations for the present study are described briefly here in chapter 1. Then in chapter 2 the influences upon timber output are analyzed: specific influences on the timber owner, such as costs and revenues, and more general influences, such as land use and the trends in forest ownership. Chapters 3 and 4 take the partly abstract material developed in chapter 2 and apply it to testing the consequences of future developments. The subject of chapter 3 is timber supply in the long run, beyond the era of old-growth conversion, when young-growth forests might be in full production. The subject of Chapter 4 is timber supply during the transition, when such questions as old-growth conversion rate and young-growth rotation length, thinning programs, and utilization are paramount.

## Some Early History

Forestry history in the Douglas-fir subregion falls into three eras, separated by the two World Wars.

In the era before World War I, the principal disposition of the public lands was completed. The National Forests were set aside, and the private timber domains of the region were founded. Timber output rose steadily, with the Puget Sound district taking the lead (fig. 2). However, the lumber industry was working mostly close to waterways, and the bulk of forests was being held for future values. Indeed, the pressure of speculative land acquisition was boosting land and timber prices by high percentages, though their level was generally low relative to today's prices.

After the turn of the century came the region's first substantial development in forestry practice, the beginning of widespread forest fire control. Shocked by the great Yacolt conflagration in Washington in 1902 and by later disastrous fires, landowners banded to form protective associations. Establishment of the National Forests brought fire control to these lands. The States strengthened their laws to promote protection. It was at this time also that schools of forestry were started at Oregon State University and the University of Washington.

## Inter-War Era

In the second, inter-War, era, the Douglas-fir subregion further increased its timber output. Paced by the Grays Harbor and other areas of the Columbia River district, and with the plywood industry rising to prominence, Oregon and Washington became top States in wood production. The shift of the Nation's forest products center from the South to the West was furthered by the opening of the Panama Canal and by the growth of export markets.

Log, lumber, and other wood-product prices showed a generally declining trend during the inter-War era, punctuated by sharp market crises following 1920 and 1929. "Overproduction" was the cry of the times, growing more shrill and despairing as the era wore on into the decade of the Great Depression. Private owners liquidated wide stretches of standing timber and abandoned much land.

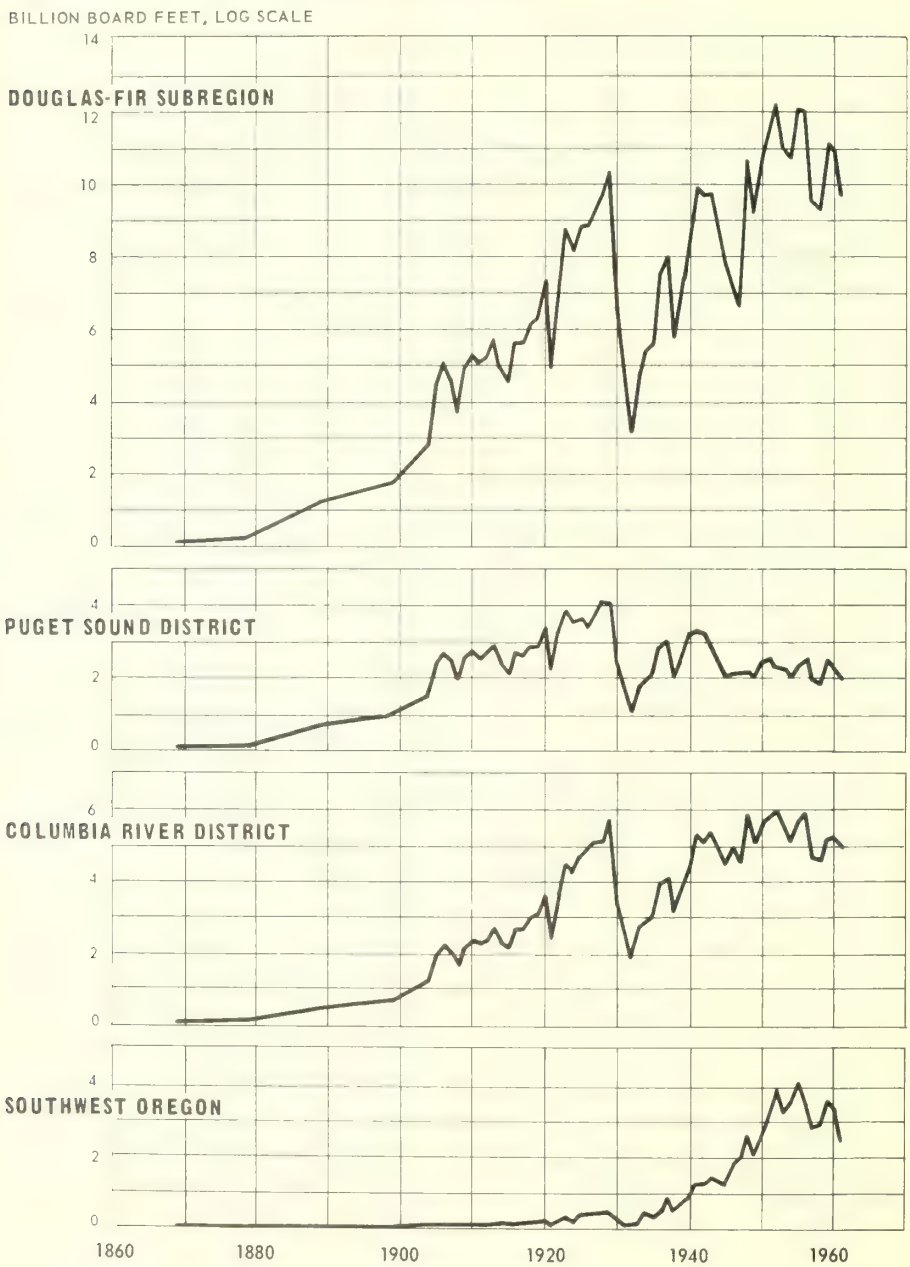


Figure 2.—Annual log production in the Douglas-fir subregion and its three districts, 1869-1961 (decennial data, 1869-99; annual data, 1904-61; production is in terms of log inventory).

From its gravest difficulties the industry harvested some notable gains for forestry. Out of the price and production problems of depression came Article X of the NRA lumber code, which, though short-lived as a legal force, started some industrial landowners on voluntary conservative programs of timber cutting and culture. Much the same basic principles were restated in the forest practice acts passed by both Oregon and Washington near the end of the era. Fire and taxation problems brought the Clarke-McNary law, which strengthened the attack on these problems. To fight "overproduction," industry spokesmen advocated sustained yield, which might prove equally instrumental in keeping output up over the long term as in keeping it down over the short term. Efforts to reduce scale of operations and to cut costs led to changes in logging and to shifts toward truck transportation, which in turn fostered a reduction in size of cutting areas and a start toward development of road networks. Both these changes helped intensify timber management. And out of the melee of timber liquidation and land abandonment came a strengthening of forest ownership throughout the region. Here and there, private firms that survived, and notably some of the big ones, made plans for retaining, restocking, and managing their cutovers.

## Current Forestry Developments

The timber-management forces that gathered during the inter-War years are being released in the current era, which began after World War II. The era has three features that are especially significant, all of them closely connected.

One feature is the rapid receding and prospective disappearance of the timber frontier in the Douglas-fir subregion, where more than eight-tenths of all the land is forest and more than seven-tenths is commercial (timber-producing) forest. Wood-using industry is pushing into the subregion's last unexploited block of counties, those of southwest Oregon (fig. 2). The industry is pushing also eastward onto long-inaccessible Cascade slopes and locally into other spots which until recently were remote. In this process, the National Forests, which include almost three-tenths of the subregion's 25-3/4 million acres of commercial forest land and over four-tenths of its standing timber (table 1), have been for the first time generally and rapidly brought into production (fig. 3). The proportion of the subregion's total log output contributed by the National Forests rose from about 4 percent in 1940 to 26 percent in 1961. Finally, the frontier of accessibility of each tree and log has been pushed back. Woods and mill utilization of comparable timber stands has in many cases increased 25 to 50 percent above the amounts that were recovered in the 1930's. Prelogging and relogging have become common. The growth of the pulp industry was particularly helpful to the utilization trend. All these developments have been attended by rapid extension of forest road networks, which in turn have made it possible to step up forest-protection standards.

## ANNUAL LOG PRODUCTION from the NATIONAL FORESTS

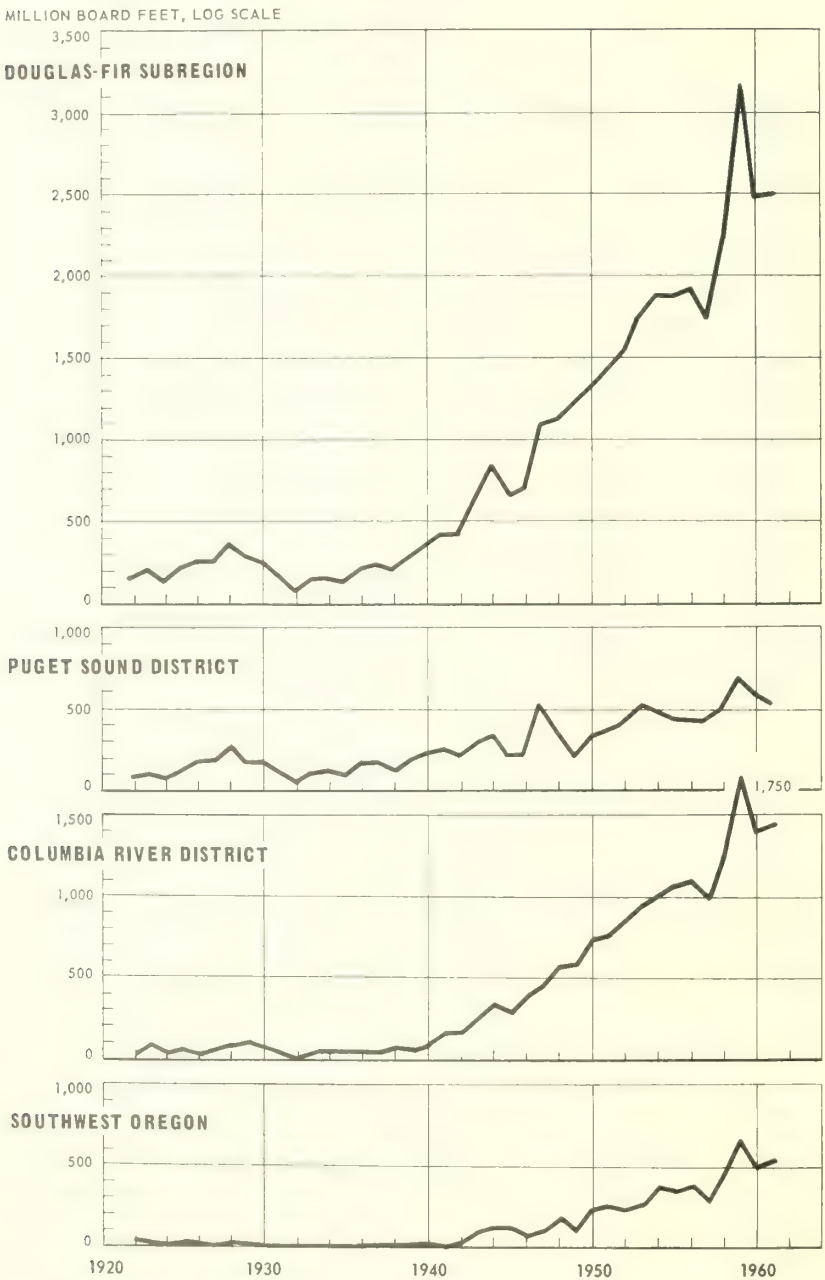


Figure 3.—Annual log production from the National Forests of the Douglas-fir subregion and its three districts, 1922-61 (production is in terms of log inventory).

Table 1. — Ownership of commercial forest land and standing timber in the Douglas-fir subregion and its three districts, decade of 1950's

| District | Private holdings | | | Public holdings | | | | All Holdings |
|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | |
| **COMMERCIAL FOREST LAND (THOUSAND ACRES)** | | | | | | | | |
| Puget Sound | 2,142 | 363 | 1,916 | 4,421 | 1,745 | 152 | 1,063 | 7,381 |
| Columbia River | 2,441 | 845 | 2,709 | 5,995 | 3,561 | 882 | 1,172 | 11,610 |
| SW Oregon | 865 | 535 | 1,496 | 2,896 | 2,187 | 1,538 | 154 | 6,775 |
| All districts | 5,448 | 1,743 | 6,121 | 13,312 | 7,493 | 2,572 | 2,389 | 25,766 |
| **LIVE SAWTIMBER (MILLION BOARD FEET, NET SCRIBNER SCALE)** | | | | | | | | |
| Puget Sound | 52,904 | 4,723 | 12,759 | 70,386 | 67,974 | 2,040 | 25,113 | 165,513 |
| Columbia River | 71,276 | 15,442 | 35,947 | 122,665 | 155,638 | 25,400 | 13,323 | 317,026 |
| SW Oregon | 35,259 | 6,807 | 21,087 | 63,153 | 61,821 | 35,189 | 4,144 | 164,307 |
| All districts | 159,439 | 26,972 | 69,793 | 256,204 | 285,433 | 62,629 | 42,580 | 646,846 |
| **ALL GROWING STOCK (MILLION CUBIC FEET)** | | | | | | | | |
| Puget Sound | 9,987 | 1,046 | 3,645 | 14,678 | 12,461 | 416 | 5,010 | 32,565 |
| Columbia River | 12,670 | 2,893 | 7,719 | 23,282 | 28,295 | 4,509 | 2,753 | 58,840 |
| SW Oregon | 5,664 | 1,361 | 4,201 | 11,226 | 12,739 | 5,842 | 767 | 30,574 |
| All districts | 28,321 | 5,300 | 15,565 | 49,186 | 53,495 | 10,767 | 8,531 | 121,979 |

[1] The resource data in this table and throughout this report are based on inventories completed prior to 1960. A considerable portion of the Douglas-fir subregion has been reinventoried since 1960 but the effect on the results of this report is considered to be minor. Acreage and timber-quantity definitions and standards are those of the nationwide Forest Survey.

[2] Large private holdings are those of owners who hold more than 50,000 acres of commercial forest land; medium, 5,000 to 50,000 acres; small, less than 5,000 acres.

A second feature of the current era, which sets it off from the one preceding, has been high and fairly continuous economic prosperity. Both the demand for wood products and the output have reached new peaks. With supplies straitened to the greatest extent in the region's history, prices of timber and its products have risen steeply. Forest land, too, has undergone price inflation as the economic prospects for timber management have brightened, and landowners, notably the large industrial owners, have striven to extend and consolidate their holdings.

The third closely related feature of the forestry trend since World War II has been the mounting interest in management of young-growth forests. Stands younger than 100 years have come to occupy half of all the commercial forest land; stands younger than 160 years, two-thirds. And if non-stocked cutovers and burns are included, the total comes to three-fourths of the commercial forest acreage (table 2). Furthermore, over 15 percent of the timber being cut now is young growth.

Table 2. — Proportion of commercial forest acreage by stand-age class in the Douglas-fir subregion and its three districts, decade of 1950's

(Percent)

| Stand-age class | Puget Sound district | Columbia River district | Southwest Oregon district | All districts |
|---|---|---|---|---|
| Nonstocked | 4.3 | 8.1 | 10.4 | 7.6 |
| 1-20 years | 15.4 | 16.9 | 7.2 | 13.9 |
| 21-40 years | 30.0 | 15.6 | 9.6 | 18.2 |
| 41-60 years | 9.4 | 9.5 | 5.2 | 8.4 |
| 61-80 years | 5.1 | 8.7 | 8.2 | 7.5 |
| 81-100 years | 4.3 | 7.8 | 7.8 | 6.8 |
| 101-120 years | 1.5 | 4.7 | 2.9 | 3.3 |
| 121-140 years | 2.2 | 2.0 | 2.9 | 2.1 |
| 141-160 years | 2.3 | 2.1 | 1.9 | 2.1 |
| 161-180 years | 1.6 | 1.2 | 2.4 | 1.6 |
| 181-200 years | 3.8 | 2.2 | 7.4 | 4.0 |
| 201 years or older | 18.8 | 15.7 | 21.5 | 18.3 |
| Uneven aged | 1.3 | 5.5 | 12 6 | 6.2 |
| All classes | 100.0 | 100.0 | 100.0 | 100.0 |
| SUMMARY | | | | |
| Nonstocked | 4 | 8 | 10 | 7 |
| 1-100 years | 64 | 59 | 38 | 55 |
| 101-160 years[1] | 8 | 14 | 20 | 14 |
| 161 years or older | 24 | 19 | 32 | 24 |
| All classes | 100 | 100 | 100 | 100 |

[1] Includes uneven-aged stands.

Little wonder, then, that recent years have seen such stress upon research in forest regeneration and in intermediate cutting and other silvicultural treatments. Increasingly, public forest owners and private owners, mostly the larger ones, are using the results of such research. With the risk of wildfire greatly reduced throughout the region (fig. 4), they have gained confidence in artificial regeneration. They are beginning to give attention, in regeneration, to seed source, to seeding techniques as well as planting, and to the use of fire as a tool. They are found here and there doing pruning and commercial thinning in stands as young as 30 or 40 years. Some of the private owners are joining those public owners that have been managing their properties in light of forest values other than timber.

And small wonder, too, in this era of adventuring into young growth, that stress has been placed on research in the economics of forestry and that the present study of trends in timber output has been undertaken.

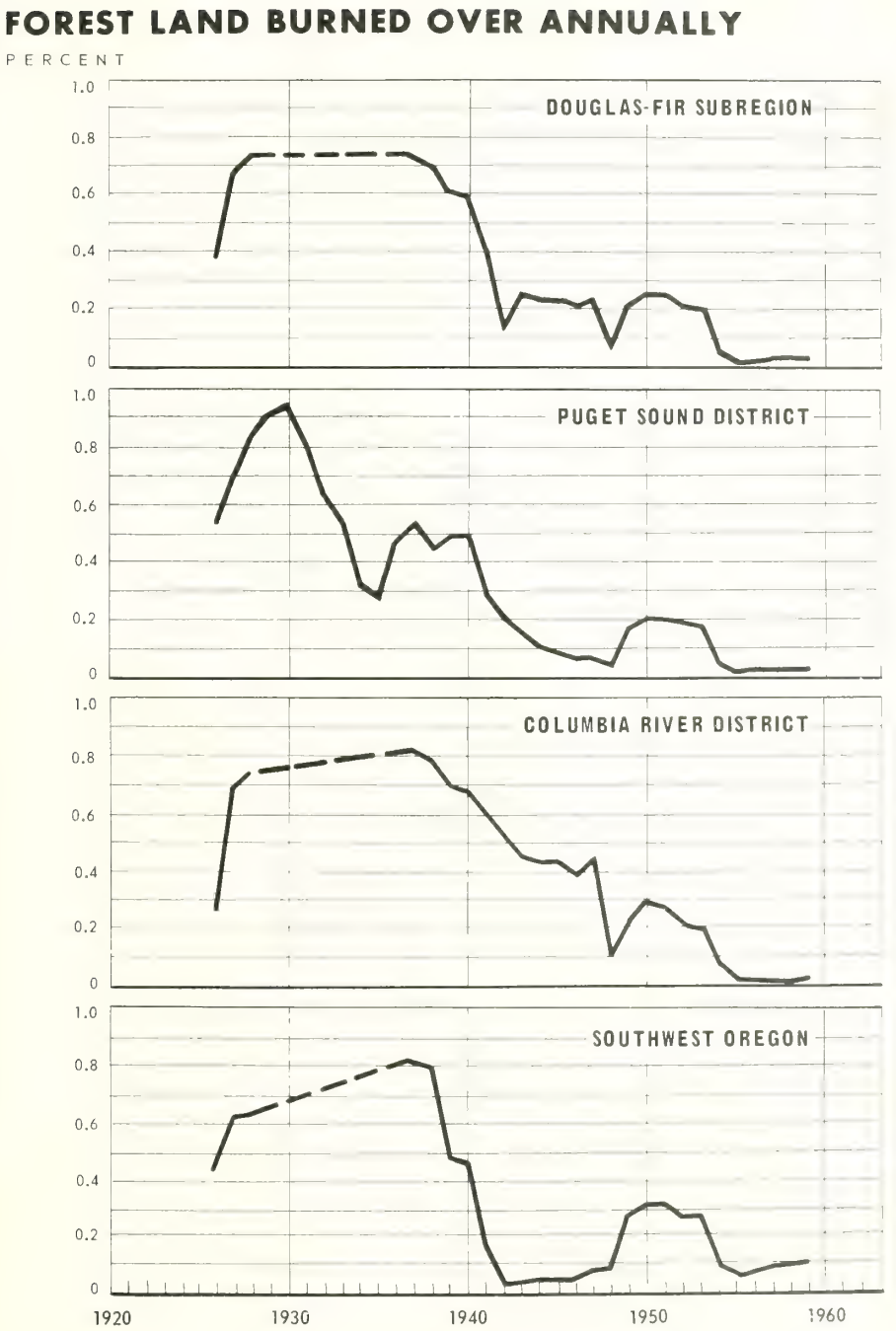


Figure 4.—Percent of commercial forest land burned over annually in the Douglas-fir subregion and its three districts—5-year moving averages, 1924-28 to 1957-61.

# Chapter 2

## Influences upon Timber Output

The purpose of this chapter is, first, to identify the main influences upon future timber output in the Douglas-fir subregion and, second, to derive some assumptions about the status of these influences.

Regional timber output will be the result of three sorts of influence. One is land use—the acreage and quality of land allocated to timber growing. Another is the management practices followed on allocated lands. Management may vary all the way from letting nature and local loggers take their course to pursuing an intensive regime of silvicultural outlays and investments aimed at improving the forest and increasing the value yield of timber. The third sort of influence upon output is bound up in the time element: it is the stage reached in the progression toward silvicultural goals. Ultimately, forest owners with the highest goals will produce the highest output per acre. But outputs in the meantime may be very differently related to goals. High-goal owners of young growth will be accumulating much timber increment as growing stock and postponing a large part of their output, while low-goal owners will most freely release such timber as they have for cutting. Owners of old growth will follow the dictates of their regulatory program in scheduling liquidation.

The following analysis of influences upon timber output will begin with the subject of the timber-management program, the practices followed on the forest lands of a given owner or type of owner. Next it will turn to questions of land use, and of the distribution of forest lands among the various types of owner. The third influence, the time element, will be given some attention along with the others in this chapter, but will be analyzed more pointedly in chapters 3 and 4.

### Management Intensity

The thing about a timber owner's management program that most nearly determines his ultimate production is the value and efficiency of his outlays upon the forest: the intensity of his management of the forest capital. By and large, the highest gross revenues from timber will in the end be earned by those owners who make the largest investments in growing stock: the amount of it, the quality of it, and the measures for stimulating its growth, protecting it from damage, and making it available for full utilization.

Timber management that involves comparatively large per acre investments in the growth of the forest is consistent with timber conservation in the sense of foregoing immediate yields for the promise of greater yields later on. Such management will here be termed "conservative" or "intensive." For an example, consider a large-scale private forest owner in the Douglas-fir subregion, a corpor-

ation with diversified wood-manufacturing plants. Such a corporation's fixed investment in its own forests—the value of land, timber, and improvements including roads—was calculated to be $1,736 per acre in 1959. Its additional current cost in that year for the labor (overhead and direct), equipment, and the like used in forest administration, protection, and culture was $1.67 per acre.

In contrast to such a conservative program is the timber management which involves comparatively small per acre costs and investments in forest growth. Management of this sort, which strongly favors today's yields over those of the future and realizes relatively little of the forest's productive potential, will be termed "exploitive" or "extensive." As an illustration, take the case of a group of small farm and nonfarm forest holdings, on sites comparable to those of the corporation's forest. Where the corporation's fixed investment was $1,736 per acre, that on the little holdings was $790. And where the additional current annual cost on the large property was $1.67 per acre, that on the small ones averaged 63 cents.

Although the more conservative timber management will produce the higher gross revenues in the long run, it is surely not in either the public or the individual interest for a forest owner to intensify his management indefinitely. How far he should go and probably will go depends on the costs as well as the revenues of his program. It may reasonably be supposed that an owner will want to earn the greatest excess of revenues over costs—the greatest net revenues—per unit of time.

The next revenues in question are not necessarily those from the owner's forest property alone. They are the owner's total net revenues, from all his resources, including any wood manufacturing, farming, or other investments that may be open to him. Furthermore, the aim of making the greatest net revenue is not confined to any particular year or period—it is equivalent to the aim of giving the owner's capital resources the highest current net worth, based upon all prospective revenues and costs of production.

The revenues and costs are those that measure all the prospective returns and all the prospective outlays that have value in the owner's eyes, dated as of the time or period when they will accrue or be accrued. They are not confined to material values or marketable things. They are meant to comprise all the items to which the forest owner himself attaches weight.

To earn the most net revenue in the sense here defined is an aim as reasonable to the public forest owner as to the private owner. For the public forest owner, revenue includes the public value of recreation, water, soil stability, and other forest benefits as well as timber, taking as public value that which considers the further future as well as the nearer future. Cost includes the public value of all the resources used up in forestry production. Consequently, the goal of managing public forests so as to earn the most net revenue is the goal most consistent with high national output and income in the broadest sense. It is not simply a financial, or money, goal. If it were, it would be no good for either public or pri-

vate policy. Rather, it is an economic goal, set in the wide context of intelligent resource allocation.

Some of the revenues and costs of forest production are hard to measure. They may need to be allowed for in part simply on the basis of judgment. However, as will be seen later on, the clear and basically simple idea of maximum net revenue or net worth permits of fitting judgment into a quantitative scheme, of measuring its effect, and thus of reducing its area of uncertainty.

In the subsections that follow, the major costs and revenues of timber management will be reviewed and their bearing upon the forest owner's management program and timber output will be discussed. It will be helpful to distinguish three classes of costs and revenues.

First are costs and revenues bearing on the owner's decisions concerning his growing stock, which is the principal determinant of his timber output. The decisions are mainly the length of rotation to follow and the average-per-acre amount of growing stock to carry at any time. The chief cost in question is interest on the value of the growing stock. This interest cost may be modified by any additional cost of converting from one level of growing stock to another. Taxes on property and on income may also be influential. The chief revenue item is value growth of timber, which is made up of physical growth and changes in the unit value of the growth—changes associated either with tree size and age or with other influences such as general inflation in timber values. Nontimber values associated with changes in growing stock also enter into the revenue.

The second class includes costs and revenues that bear upon the owner's decisions about silvicultural and protection measures and the degree of utilization of standing timber—items that affect output by affecting the efficiency of a given growing stock. The costs in question include those of labor, supplies, and taxes and of the maintenance and depreciation of equipment and improvements related to the technology of silviculture and forest engineering. Costs may also include interest charges upon outlays. The components of revenue are the extra timber yields attributable to the outlays, the timber price level, and, as before, nontimber values.

Third are those costs and revenues that bear on the owner's decisions about holding, acquiring, or abandoning forest land. Costs and revenues include the same items as in the first two classes, as of the period relevant to longrun investment decisions. Included also is the price of forest land for acquisitions or disposals.

Costs and revenues will be taken up in the following order: (1) interest on capital, (2) tree value in relation to age, (3) timber value trends, (4) timber value levels relative to costs of silviculture, including forest development and protection, and (5) taxes. After that, land use and forest-land ownership will be discussed.

## Guiding Rate of Interest

The rate of interest at which a forest owner compounds and discounts values and makes other time comparisons will be called his guiding rate of interest. What

bearing does the guiding rate of interest have upon timber output, and what will be the magnitude of the rate for various forest owners?

Relation of guiding rate to timber output.—A hypothetical Douglas-fir forest on site III is used for illustration. Site III is medium quality, with an average index of 140 (tree total height in feet at 100 years of age). The forest is of even-aged character, being in this respect representative of most forests in the region (table 2). It is assumed for simplicity that the owner will manage the forest under a one-cut-per-rotation system and that he expects to get the yields estimated in the normal yield table (6, p. 27): the yields in board feet by the Scribner rule, considering trees 11 inches[1] and larger in diameter to a minimum 8-inch top inside bark. It is further assumed that he assigns to the yield a value of $10 per thousand board feet; this assumption, too, is just for simplicity's sake, for in fact the choice of value has no effect upon the answer to the question now to be explored: What is the influence of the owner's guiding rate of interest upon his prospective timber output?

Columns 1 and 2 of table 3 are copied from the normal yield table. In this illustration, column 2 should be thought of as estimates of the harvest cuts obtainable from 10 alternative hypothetical forests with rotations ranging from 30 to 120 years and with 1 acre of forests representing each year of age.

[1] The 12-inch diameter class of the normal yield table, based on 2-inch classes, includes trees down to an 11.0-inch minimum.

Table 3. — Rate of return on extra growing stock as related to average annual timber yield per acre of 10 hypothetical regulated Douglas-fir forests on site III managed for one cut per rotation

| Rotation (years) | Yield | | | | Growing stock | | | Return on extra growing stock |
|---|---|---|---|---|---|---|---|---|
| | Cumulative | Annual per acre | | | Cumulative | Per acre | | |
| | | Total | | Extra | | Total | Extra | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | Board feet | Board feet | | | Dollars | | | Percent |
| 30 | 300 | 10 | 0.10 | -- | 15 | 0.50 | -- | -- |
| 40 | 4,500 | 112 | 1.12 | 1.02 | 255 | 6.38 | 5.88 | 17.3 |
| 50 | 12,400 | 248 | 2.48 | 1.36 | 1,100 | 22.00 | 15.62 | 8.7 |
| 60 | 23,800 | 397 | 3.97 | 1.49 | 2,910 | 48.50 | 26.50 | 5.6 |
| 70 | 35,200 | 503 | 5.03 | 1.06 | 5,860 | 83.71 | 35.21 | 3.0 |
| 80 | 45,700 | 571 | 5.71 | .68 | 9,905 | 123.81 | 40.10 | 1.7 |
| 90 | 55,000 | 611 | 6.11 | .40 | 14,940 | 166.00 | 42.19 | .9 |
| 100 | 62,800 | 628 | 6.28 | .17 | 20,830 | 208.30 | 42.30 | .4 |
| 110 | 69,400 | 631 | 6.31 | .03 | 27,440 | 249.45 | 41.15 | .1 |
| 120 | 75,000 | 625 | 6.25 | -.06 | 34,660 | 288.83 | 39.83 | -.2 |

The yields of column 2 are anticipated yields per acre, from those acres that have reached rotation age. If the forest property is regulated, with an equal acreage devoted to each 1-year age class of timber, so that an even annual flow of stumpage may be produced, then the average annual yield per acre of the entire forest is the yield of column 2 divided by the rotation of column 1—that is, the mean annual growth per acre, as computed in column 3. The board foot yields of column 3 are converted to dollars in column 4 at the fixed rate of $10 per thousand feet.

The yields of column 3 or 4 are alternatives just as are those of column 2. However—arising, as they do, in a regulated forest—they are long run alternatives: The forest owner cannot shift at once from one rotation to any other he may choose; he will need to do some recompartmenting of the forest and to wait out a rotation before the new program is fully in effect.

From a study of column 4, it is evident that for rotations up to 110 years, the value of the average annual yield per acre can be increased by planning a longer rotation. The amount of the increase from each 10-year lengthening, the "extra annual per acre yield," is figured in column 5. Each extra yield represents an advantage of the longer over the shorter rotation and is, therefore, a basis for comparing the alternatives. Were there no counteracting disadvantages, no costs or penalties of stretching out the rotation, the best length of rotation (the one that would fulfill the owner's aim of earning the highest net revenue) would be set by the culmination of mean annual growth at 110 years. And the timber output at which the owner should aim would be 631 board feet per acre per year. But of course there are such costs and penalties. The consequence of them is to shorten the rotation and reduce the output for the forest owner.

The principal cost or penalty in question is the necessity for carrying more growing stock in order to lengthen the rotation and raise output. Column 6 in table 3 shows the approximate value of growing stock that would be present in a regulated forest where one acre was devoted to each 1-year age class of timber up to rotation age. The simplifying assumption is made that young timber up to 25 years of age has no (merchantable) value, that all timber from 25 to 35 years has the same value as 30-year timber (300 board feet at $10 per thousand, or $3 per acre), that all timber from 35 to 45 years has the value of 40-year timber ($45 per acre), and so on. Thus, 30 acres of regulated forest on a 30-year rotation would contain 5 acres of timber with merchantable value: those where ages ranged from 25 to 30 years, with a value of $3 per acre or $15 altogether (col. 6). And 40 acres on a 40-year rotation would contain a similar 5 acres, plus another 5 (aged 30 to 35) worth another $15, plus 5 more (aged 35 to 40) worth $45 X 5, or $225. Adding these values of the 40-year forest gives the $255 figure in column 6.

It should be explained that when a perfectly regulated forest is assumed, as in table 3 and in other similar tables and calculations in this report, this is not to imply that today's managed forests are in fact perfectly regulated or that those

of the future will be. The analyses in this report are intended to apply to real forests managed for continual yields. Table 3, stylized as it is, is meant to represent as closely as possible, on the average, not the form of these real forests, but the reasoning and conclusions applicable to them.

Let us return to the mechanics of table 3. The average value of growing stock per acre is found by dividing the column 6 values by the corresponding acreages, or rotation periods. Clearly, the value of growing stock that must be carried on the average acre (col. 7) increases with rotation and output. The amount of the increase for each 10-year lengthening of rotation, the "extra growing stock per acre," is worked out in column 8. Column 9 is simply column 5 divided by column 8, or the extra yield divided by the extra growing stock. It is a rate on the extra growing stock required to establish a 10-year longer rotation. This is not an average rate, nor an annual rate for any point of time. It is not even a periodic annual rate, for it refers to alternative completely regulated forests with uniform distribution of age classes representing each year of each rotation, rather than the same stand simply held 10 years longer. Actual rates of return for a given stand would have to be calculated by other methods, as described in standard forestry texts.

From this point, it is a simple matter to estimate, at least as a first approximation, the annual output for which the forest owner would aim. Suppose, for example, that the owner is weighing a 60-year rotation against a 50-year rotation. In the case represented by table 3, the longer rotation necessitates carrying $26.50 more growing stock per acre (col. 8) than the shorter one. That is to say, the longer rotation requires indefinitely tying up $26.50 per acre in standing timber—money which under the shorter rotation could be put to some other use. It could be spent for consumption, invested, or used to repay a loan.

Which alternative is the better—to invest the $26.50 in growing stock or to use it for some other purpose? If the owner's aim is, as assumed, to earn the highest net revenue from all his resources, the answer is clear: put the $26.50 where its net efficiency will be highest. Invested as growing stock, the $26.50 promises to increase the annual timber yield $1.49 (col. 5), or 5.6 percent (col. 9). If the owner can do better than this elsewhere, then presumably he will put his money elsewhere—that is, follow a rotation no longer than 50 years and produce a timber output of no more than 248 board feet per acre per year. But if the owner cannot do better than a 5.6 percent return elsewhere, then surely his aim will be to make the extra investment in growing stock, follow a rotation of at least 60 years, and produce an annual output of 397 or more board feet per acre. (In judging the rotations found in table 3, remember that the table illustrates a one-cut-per-rotation case. Under a thinning regime, as will be brought out later, indicated rotations are longer.)

Thus, the forest owner's decision about timber output in this case may be viewed as depending upon the efficiency of his alternative uses of funds—that is

to say, his alternative rate of return, or guiding rate of interest. Columns 3 and 9 of table 3 then show the owner's long run alternatives as a function of his guiding rate of interest.

Table 3 takes no account of any cost, other than interest on growing stock, of converting from one level of stock to another. Such cost may include that of engineering the converting process (compartmenting and roading the forest property and so on) and that of waiting for yields while the process is underway. If the converting is from a more to a less intensive program, the cost may be negative. The net amount of it will depend on the circumstances of the property. Because of the variability of converting cost and the likelihood that it will include negative elements offsetting the positive, the net amount of the cost is assumed, in this case and hereafter, to be negligible.

Table 3, then, illustrates the general relationship between a forest owner's longrun timber goals and his guiding rate of interest: the lower his guiding rate, the lower the rate of return he demands from his timber capital, the more such capital he is willing to carry before shifting some to other uses, and the higher his planned annual output of timber. When an owner manages his forest at a 5-percent or a 3-percent rate of interest, it means that he is trying to arrange his capital in such a way that it will increase in value at a rate never less than 5 percent or 3 percent.[2]

Maximizing the mean annual growth.—The decision of a forest owner to set his rotation age at the culmination of the mean annual volume or value growth may be analyzed in terms of table 3. Under the simplified assumptions of this table, such a decision means that the owner is following a guiding interest rate of 0 percent. He is ensuring only that none of his capital will earn less than nothing. That is to say, he is not shifting capital unless the capital otherwise would be destroyed. He is withholding some capital from all the alternative uses in which it has any positive value. Such a decision would be appropriate only for an owner who had no productive alternative uses for funds. If an owner has access to any outlet for investment or spending that will earn him any net revenue at all—that is, if the capital has any value to him—then he cannot economically follow so long a rotation or produce so high an output.

It is scarcely surprising to find that the forest owner will normally aim for less than the culmination of mean annual value growth. Seldom in economic life does one find a producer aiming at maximum output. The farmer does not use all the

[2] The approach used in table 3 is analogous to selecting the regulated forest which maximizes the present worth of the land. In this case, the present worth of land per acre is equal to the capitalized value of the average annual yield per acre, given in column 4, minus the present worth of the average growing stock per acre, given in column 7. Thus, for a guiding rate of 3 percent, the 70-year rotation in table 3 not only indicates the optimum amount of growing stock capital for the regulated forest but also maximizes the present worth of the land. Both approaches assume there is no stocking alternative for the land in the long run except a balanced age class forest producing even annual yields so long as the land is to be used for timber growing.

fertilizer that might serve to enlarge his crop. The mine owner does not hire more miners so long as they give him any increase at all in his production. A reasonable program respecting either fertilizer or miners is to add more so long as they pay their way, and likewise a reasonable timber program is to add more growing stock only so long as it promises to pay its way in terms of additional yield. From the standpoint of the individual forest owner, to maximize the mean annual value growth is to incur certain costs that fail to yield commensurate returns and thus to reduce net revenues; from the standpoint of society, it is to increase timber output at the expense of a greater value of other goods and services and thus to reduce national income.

And so it becomes apparent why a policy of maximizing the mean annual growth does not contribute, as intended, to abundance. The policy does, of course, contribute to timber abundance. But at the same time it subtracts from the national product other goods and services with a value greaer than that of the timber added.

Guiding rate as reflection of nonforest revenues.—From the foregoing thoughts it is a small step to the realization that since an owner's guiding rate of interest is set by his best alternatives, whether within forestry or outside, the use of this rate in setting the timber program is consistent with the owner's aim of earning the greatest return from all his resources, forest or not.

The forest owner should plan to lengthen his forest rotation so long as the marginal return (col. 9) is above his guiding rate. Among the rotations shown in table 3, for example, the forest owner with a 4-percent guiding rate should choose a 60- rather than a 70-year rotation, earning a return of $3.97 per acre per year. Indeed, from the standpoint of total earnings, this program does show up as the best of those listed. Rather than follow a longer rotation, such as 70 years, with its investment of $83.71 per acre and its yearly earning of $5.03, the owner would do better to put $48.50 into growing stock on a 60-year rotation, invest the remaining $35,21 at his alternative 4 percent, and garner the resulting $1.41 in addition to $3.97 of forest income, for a total revenue of $5.38 altogether. Similarly, it can be shown that any rotation shorter than 60 years is, for this owner, inferior by the standard of total returns from all sources.

Looking at the matter from the regional or national view, one finds his attention directed to the manifold resources that nourish the economy. One sees that these resources are necessary to produce an output—of timber or of anything else. They are the means of production—the means of livelihood—and they are scarce. Resources tied up in any use are thereby withheld from other uses. Consequently, in order to achieve abundance—high income, wealth—a community or nation tries to put its resources into those uses that will yield the most valuable output, and to keep shifting resources from purposes that are less valuable to those that are more so. Obviously, in most cases it is in the interest of private individuals and firms thus to direct and shift their resources. For the community and nation, interest in such behavior is even more certain and clear. Assuming a fairly consistent standard

of value, the community and nation are in position to gain whenever any owner of resources, private or public, shifts them from less to more valuable uses.

Fixed interest costs in relation to timber output.—So far, this study has concerned the influence of the costs of holding timber growing stock. What about costs of holding other sorts of investment?

These other costs, unlike those of holding growing stock, fall into two distinct classes. First, there are the costs of holding investments such as roads, which may vary with timber output per acre of forest land. The variation arises through the relation of the road outlays to other forest practices: protection, thinning, and the like. This class of interest cost can be discussed most easily along with silvicultural costs.

Second, there is the cost of holding land—the interest on the land investment. This cost has a bearing on timber output through its influence upon land use, and this bearing will be brought out when the land-use topic is analyzed. Beyond the land-use effect, the interest cost of holding land has no relation to the rational program of timber management. So long as the land is used for timber growing, the investment in it is a fixed cost of production and should have no bearing upon output. Among the alternatives in table 3, a 60-year rotation and a 397-board-foot yield is the best timber program for the owner whose guiding rate of interest is 4 percent, whether he paid $1 per acre or $100 per acre for his land.

It is sometimes asserted that a heavy investment in land, or other large fixed carrying charge, forces a forest owner to manage his timber for higher yields than would be necessary otherwise. The point is made that only by raising the yield and thus the revenue can the owner earn enough money to defray these high charges. This assertion overlooks the other costs of timber growing just as does the philosophy of mean-growth culmination. Consider the owner, taken for illustration earlier, who plans a 60-year rotation. This owner's net revenue may represent a poor return on his investment in land. But surely he cannot better himself by increasing his rotation and his yield if the outcome will be simply a lower net revenue than before. Perhaps he can better himself eventually by getting out of the forest business. And perhaps prospective investors in forest land can appraise the anticipated return from timber in light of their guiding rates of interest and avoid paying too much for the land. Investment responses such as these may lead to changes in land use and to an adjustment of forest-land market values in line with realizable revenues. But so long as an owner's investment cost of land is fixed in reference to output, it is irrelevant to his output (and rotation) decision.

Time of reference for guiding rate.—Before it will be possible to speculate about the future guiding rates of interest of actual forest owners in the Douglas-fir subregion, it will be necessary to identify the future period or periods to which the speculation should relate.

The periods with which this study is concerned are the longrun and the transition period. The long run is that time which is far enough in the future so that

any of today's timber properties could, if it were so desired, be converted over into a forest with a normal distribution of age classes. The distribution would depend upon the chosen length of timber rotation. For the subregion in general, the long run lies at least as far in the future as the longest rotation in prospect. The transition period is the time intervening between now and then—with special emphasis, in this report, upon the next 40 years.

The dates, therefore, that are relevant to speculation concerning the rate of interest that will guide decisions about the long run are all the dates when planning for the next generation of timber may be carried out. These dates extend throughout one rotation, beginning now. The dates that apply in the case of the transition are the same, but with emphasis on the earlier dates.

Determinants of guiding rate.—What determines an owner's guiding rate of interest for timber management at any particular time? Four kinds of determinants need to be recognized.

First, the guiding rate is generally governed by the prospective rate of return from the most efficient alternative use to which the owner's resources may be put. One such use is investment or spending within the owner's business, as on forest land, timber management, or wood processing. Here, the rate that governs is the anticipated annual rate of return from this use or the owner's borrowing rate, whichever is less after allowance for risk. Another alternative use is investment outside the owner's business, as in the securities of some borrower, and here the rate that governs is the prospective yield from the securities. Still another alternative is spending for personal consumption. This type of use is most apt to be controlling for the small-scale individual owner. Judging his rate of return is a subjective process: The rate is conceived to equal the owner's rate of "time preference"—the premium he places on current consumption in preference to postponement.

Second, the guiding rate of interest is affected by various fringe benefits that may accompany the income from forestry or its alternatives. As it happens, many of these fringe benefits are attached to forestry rather than to the alternatives. For the owners who are in position to enjoy these benefits, the guiding rate of interest applicable to their forestry enterprises is lowered: Considering the fringe benefits, forest management does not need to yield so high a return as otherwise in order to compare favorably with its alternatives. Among the benefits in question is the long-term capital gains provision of the Federal income tax, which favors timber growing. Also notable is the benefit that accrues to wood manufacturers who own timberland. Their landholdings are the means for securing their timber supply and thus for securing their profits of manufacturing. To the public forest owner, fringe benefits come from timberland in the form of nontimber resources created and in the form of all resources stockpiled to insure current abundance and conserved to benefit prosperity. When the forest performs so strategic a function for the owner, he may be content with a relatively low intrinsic revenue from timber management.

Third, the owner's guiding rate of interest for forestry is influenced by his judgment of the relative risks (and uncertainties) in forestry as compared with the alternative objects of investment or spending. The risks in question are those of physical loss, as from fire, pests, and storms, and loss in value because of declining price or rising cost. The higher the risks in forestry relative to other enterprises, the higher the guiding rate of interest—that is, the more the forest enterprise has to earn in order to be comparatively attractive.

Fourth, the guiding interest rate is modified by any costs that the forest owner might need to incur in order to transfer his funds from timber into other investments. For the private owner, income taxes are the principal transfer cost. In shifting investments from the forest into other enterprises, the private owner subjects himself to one extra income taxing beyond what would be involved in the absence of the shift. The result is to lower the guiding rate of interest management, reducing the required rate of return by the percentage of the extra tax.

Changes in guiding rates over time.—To come back to the question of the date or period of reference for estimating an owner's guiding interest rate applicable to his planning for the long run and transition, it is clear from the foregoing analysis of determinants that the rate will vary and change over time. It will vary with the cycles in building activity and in business at large. It may vary seasonally, and it will vary irregularly with changes in the owner's situation and prospects. For example, the industrial owner's guiding rate will tend to move with his shifting judgment of risks and with changing prospects for other than forest investments. And the owner of the small woodland will operate at a comparatively high rate at times when his income prospects are poor or when he has heavy personal expenses to meet. All such fluctuations are rapid in comparison to the lengths of time over which timber-management planning is done and management decisions exert their influence upon the condition of the forest. Consequently, the effective guiding rate during any timber-cutting cycle or rotation is apt to be the highest rate that obtains during the period. That is to say, one may need to look at the upper range of values attained by the rate in the course of its fluctuations in order to judge what interest guide is in effect in the forest.

Beyond the short term, what changes may be expected in the guiding rate of interest—that is, in the upper range of it? Is it reasonable to anticipate a trend for the long run? Many of today's economic developments suggest a rising trend: for example, the fact of expansion in the economy and in its investment opportunity, the public policy emphasis upon rapid economic growth, the stress placed upon consumer goods in our economy, the wide choices continuously being multiplied that are offered to the consumer, the growing pressure of advertising upon the consumer.

However, in the present analysis, all reasonable weight will be attached to the contrary influences—those which will hold down the guiding rate of interest and thus favor intensive and conservative timber management. Among such influences are continuing risk reduction in the timber economy, the prospect of high

taxation of income, the opportunities for wood in general to enhance its status in our economic life, and the public efforts that will be made to bend guiding rates in the direction of the public interest.

And so it is assumed that the guiding rate applicable to each class of forest owner will show a horizontal trend in the future—that the rates effective during the time considered in this study are the upper-range rates effective today. In any case, the rates of today and the near future carry the most weight in a series, regardless of its length.

Explicit and implicit rates of forest owners.—It appears that for many forest owners the guiding rate of interest is an explicit tool of management, consciously and deliberately used for the purpose of making decisions about forest investments and spending. For example, one large manufacturer of lumber and plywood in southwest Oregon sets his timber rotations at that age which will permit the crop trees to grow at no less than a 3-percent annual rate until harvest time. This basis for the rotation and output decision is roughly the same as that developed in table 3.

Another firm in the same area, a veneer and plywood manufacturer with some 50,000 acres of forest land, aims to carry its timber investments to the point where its stumpage output, valued at market prices, will cover its cost compounded at the borrowing rate of interest, which it figures at 4 percent. This rate of return is an average rate on all outlays, in contrast to the guiding rate of interest as conceived in this study, which relates only to the last or least efficient outlays. Translated into guiding-rate terms, the firm's rate becomes somewhat less than 4 percent.

A lumber manufacturer in the Columbia River area, a family-owned concern with relatively modest holdings of forest land, uses an interest rate of 7 percent to guide its forest outlays. In setting this rate, the firm makes deliberate allowance for certain risks of which it is sharply aware, such as the risk of higher taxes and the risk of having to sell its forest property on an undependable market.

A pulp and paper company in the Puget Sound area has a vigorous land-acquisition program. This company sets its ceiling prices on tracts for prospective purchase by discounting anticipated net revenues at 3 percent as a guiding rate of interest.

Although many forest owners use guiding interest rates, no owners base all their management decisions upon an explicit rate; even if they wished to do so, imperfect knowledge of the costs and yields entailed in forest practices would prevent it. Furthermore, a great number of forest owners, particularly owners of the smaller tracts, do not use an explicit guiding rate of interest. Their decision-making process is not so orderly or so precise as to require or permit following a numerical guide.

And so, many a firm sets its forest rotation at the age when growth rates threaten to drop off below an acceptable level but does not attempt to apply this management principle precisely in cost-revenue terms. And many an owner whose finances are cramped brings his forest rotation to an end when he gets his first chance to sell his timber—or at least when the next urgent need arises for cash.

Whether the owner's basis for forest-management decisions is logically interpreted accurate data, very general judgment, or merely an impulse, every decision at least implies a guiding rate of interest. Where costs and revenues can be predicted, the rate implied can be calculated. And often the calculated implicit rate for a particular owner is found to be consistent from one decision to another.

In this study, the idea will be accepted that the rate of interest is a meaningful an realistic tool for making forest-investment decisions and for interpreting, understanding, and forecasting the decisions of forest owners. It will be recognized that guiding rates vary a great deal among owners. But it will be assumed that for each owner the rate—that is, again, the upper range of it—is essentially uniform and that there is much consistency, also, among owners similarly situated. It will be assumed that consistency on the part of an owner arises at least through the working of his general judgment, that consistency among owners is favored by their imitation of one another, and that consistency will increase as more silvicultural facts become known and as knowledge spreads. Thus, it will be maintained that owners lend themselves to a grouping or classification on the basis of the magnitude of their guiding rates, the rates within each owner group being closely similar.

Conservative large-scale corporate owners.—Among forest owners with a notably strong leaning toward intensive, or conservative, timber management are many of the big-scale, highly integrated, and diversified forest-products manufacturing corporations which provide themselves with raw material from their own large landholdings, normally well over 50,000 acres.

The typical firm in this class looks to its plant investments as its primary source of profits and would like to expect a high rate of return from these investments. From its timber resources it expects a sustaining flow of raw materials, protection from the vagaries of the open market, and thus security in its profit position, but ordinarily only a low intrinsic rate of return. To be sure, the firm has enjoyed a rapid rate of growth in the value of its forests as a result of land and timber price inflation, and it may foresee a continuance of such growth. But this fact only makes the firm more content with a low rate of value growth from within the forest.

Its raw material interests lead the firm to organize its landholdings for conservative management under intensive professional supervision, to try a wide range of silvicultural programs, to practice close utilization of wood in the forest as well as in the mill, and generally to take the lead in the forestry developments that characterize the current era.

The firm's risks of timber management appear to be low. With extensive landholdings, risks of physical loss are well spread. Risks of value loss are commonly judged to be negligible: specific forest products may lose favor in consumer's eyes as time goes on, but the value of wood in general as raw material is regarded as secure. Its corporate form enables the firm to take a long and continuing view of its business and to plan ahead to distant horizons that are undisturbed by considerations of the life span of today's decision makers.

The guiding rate of interest to be taken here as representing the timber management of this class of firm is 3 percent.

Federal Government as a conservative owner.—Another forest owner generally believed to function at a low guiding rate of interest is the Federal Government. Federal planners weighing prospective investments in resource development have often used interest rates of 2-1/2 or 2 percent. Sometimes it is held that the rate to use is the carrying charge on the national debt, which now runs about 3 percent. Some studies suggest a rate as high as 5 or 6 percent (4). In any case the rate sought is, like that for private concerns, an alternative rate of return adjusted for fringe benefits, risks, and transfer costs.

The Federal Government's timber investments are, in the last analysis, financed by taxation. That is to say, the Government's alternatives are (1) to take timber income, as through liquidation, or otherwise refrain from investment and (2) to raise the funds by taxation. Under conditions of full employment, the appropriate guiding rate of interest to be used might be set at the estimated average rate of return that private individuals and firms may expect to earn on their resources and thus contribute to the national product were they not to transfer the resources to the Government in the form of taxes. The implication is that the Government must foresee earning at least as high a rate as this in order to justify its investment and its attendant taxing.

However, a number of considerations are arguments for holding the Federal rate for timber-growing investments below such a level as 5 or 6 percent. One is the existence of fringe benefits of Federal timber management: benefits from nontimber values and from pursuance of the national conservation policy to alter resource use in favor of future generations. Among fringe benefits may also be included that of helping to secure the national raw-material supply, a benefit to society analogous to what the integrated private firm enjoys, and similarly serving to lower the guiding rate of interest. Another consideration is the longrun obligation of the Government to offer the Federal forests as examples of successful conservative practice. It would be scarcely rational for the Government, with its paramount long-term interests and its responsibilities for the wood supply, to manage its own holdings generally at any higher a guiding rate than that appropriate for the group of most conservative private owners.

The guiding rate of interest chosen here to represent the forest decisions of the Federal Government is 3 percent.

It is well to emphasize what it means to choose an interest rate, such as 3 percent, to signify the forest-management policy of the Federal Government. Most notably, it means that one is assuming an economic aim for the Federal forests: the aim of making—not money primarily—but net revenue in the form of all the materials and services of the forest that have public value, over the whole span of time for which the public is concerned.

Thus, in choosing an interest rate, one simplicity accepts the economic aim of continually shifting capital and other scarce resources from less into

more valuable uses: the aim of substituting, wherever possible, a revenue for a cost.

Of course there is always the question whether, under the economic approach, revenue and cost are acceptably measured.

Consider, for example, the important matter of forest rotation length. Does not the economic approach belittle the intangible values of scenery, water, wildlife, and so on? And is not the economic rotation, therefore, too short? Again, is not forest management peculiar in respect to the long period of production it involves? and does this not imply that exceptionally long-range planning is necessary in forestry? Does it not also imply the need for exceptionally high allowances for emergencies—that is, extra large ultimate outputs, such as one may get through the use of extra long rotations? Is timber, perhaps, peculiar among resources in that the public may quite properly subsidize the holding of it at the apparent expense of other resources?

There are, indeed, imponderables and other special elements in public forestry which must be accounted for in any acceptable management procedure. Those elements which give rise to extraordinary values for older or larger timber—for instance, scenic values—militate toward longer rotations. Conversely, other elements may favor shorter rotations or be quite neutral in respect to rotation length. In general, the goal to be pursued is to create the greatest possible sum total of net values on the public forests. The economic rotation as developed in this report is an idea consistent with such a goal. The difficulty, admittedly, is choosing the right values to use in calculating the rotation. The choice must rest partly on judgment—such as the judgment of a 3-percent guiding rate of interest for Federal forestry. At least the judgment can be applied—and is believed to be applied here—with explicit recognition of the issues involved.

Exploitive forest owners.—It will be helpful to turn from the forest owners with most conservative leanings to their antitheses, the owners with most exploitive leanings. In this contrasting class are to be found some private forest owners of nearly every size group and type. However, the sort of owner that comes closest to typifying the class is the small-scale individual or family owner whose principal interests are other than the forest and whose principal income likewise is from other sources and is meager by the standards accepted in the community.

Such an owner is apt to be poorly acquainted with the potentialities of timber management. He is poorly equipped, in view of his economic insecurity, to take advantage of such knowledge as he may come by. His planning outlook as well as his tenure is likely to be short. His timber-management practices are the result not so much of his own decision as of the convenience and importunity of local loggers, who keep the forest trimmed back to the extent that its merchantability permits.

The guiding rate of interest of such a forest owner is influenced by the fact that consumption alternatives of high priority commonly govern the owner's aware-

ness of timber-management risks, associated with protection, utilization, marketing, and other phases of the adventure. The consequence of influences of this sort is a high guiding rate of interest: 10 percent, 20 percent, or often much more. A rate may be so high that it greatly exceeds the top rate of value growth of which the forest is capable. Such a rate suggests merely that the owner who has no other use for forest land will sell timber from it as often as there is timber to sell and someone willing to buy. Thus, beyond a point, the magnitude of the rate can have little influence upon timber output, which will already have fallen approximately to the minimum consistent with successful tree regeneration.

Here, to represent the exploitive class of forest owners, a guiding rate of interest is chosen which is about as high a rate as can generally be given a silvicultural interpretation. The rate chosen is 12 percent.

Owners with intermediate guiding rates.—The range between the class of conservative owners with a guiding rate of 3 percent and the class of exploitive owners assigned a 12-percent rate is here looked upon as a single intermediate class. For this class, the mean rate of 6 percent is assumed to be the guiding rate of interest.

In this intermediate class fall some owners of large forest holdings and also many owners of small tracts who have special motivation for timber growing. It is assumed that the bulk of this class is made up of State and local government and the family-owned wood-manufacturing concern with a middle-size forest holding. These owners are distinguished from the most conservative class in being confronted with higher risks of timber production and in having a more restricted horizon in their planning for the future.

Specific assumptions about the future acreage of commercial forest land in each of the foregoing three classes of ownership will be developed in a later part of this chapter, where the subject of ownership trends is analyzed, and in chapter 3.

Guiding rate as a comprehensive value index.—Let us summarize the point of view taken in this study with respect to the guiding rate of interest. The rate is regarded and employed as an index of all those considerations that may affect a forest owner's valuation of capital and by this means enter his decisions about using capital: the amount of it, the purposes to which it will be allocated, and the timing of its use. Such decisions are, by a wide margin, the most influential in forestry; in great measure, they determine the output of forest materials and services. Consequently, it is a large role that is here assigned to the guiding rate of interest.

Although some forest owners consciously use an interest rate to guide their judgements, many—and indeed, the great majority—do not. However, whenever a decision is made about forest capital, whatever the basis for the decision, a rate of interest is implied and can be derived. The use, then, of a guiding rate in the present analysis merely assumes two things. First, it assumes that the forest owner is consistent, in time and among the objects of investment and spending, in respect to the value he attaches to capital. Second, it assumes that this value, this implicit

guiding rate of interest, can be closely estimated for a class of owners and that it is so estimated in this instance.

The resulting rate of interest is intended to reflect the owner's ability and desire to use forest capital, not only to make wood but also to furnish recreational and watershed services and other forest tangibles and intangibles now and in the future.

## Tree Value in Relation to Age

The source of forest revenues, so far as wood is concerned, is the value growth of timber. Table 3 illustrates how value growth defrays the cost of holding growing stock and makes it profitable to postpone the harvest for a while, meantime augmenting the ultimate output. It will be remembered that value growth in table 3 derives only from volume growth—a fixed timber value of $10 per thousand board feet is assumed.

However, a forest's value growth may arise from more than just its production of volume growth as in table 3. Value growth may come also from (1) lower conversion cost per unit volume with advancing size and age, (2) the prospect of forest reestablishment costs following the harvest, (3) improvements in timber quality (higher product value per unit of timber volume), and (4) inflation of timber values relative to the general level of values in the economy. The first three of these influences will be taken up at this point; the fourth, in a later section.

Nature of effect of conversion cost differentials and reestablishment costs on timber yields.—Suppose that, as a result of a prospective lowering of conversion cost with age, the anticipated value of the Douglas-fir stand of table 3 is not constant at $10 per thousand board feet, as assumed there, but increases from $10 at 30 years of age at a rate of 1/2 percent per year:

| Stand age (in years) | Value per M board feet (in dollars) |
|---|---|
| 30 | 10.00 |
| 40 | 10.51 |
| 50 | 11.05 |
| 60 | 11.61 |
| 70 | 12.21 |
| 80 | 12.83 |
| 90 | 13.49 |
| 100 | 14.18 |
| 110 | 14.90 |
| 120 | 15.67 |

In this event, the value growth—expected percentage return of column 9—is increased. Table 4 displays the alternatives with which the forest owner is now confronted and compares them with the table 3 alternatives. It suggests that, in the range of interest rates from 12 to 3 percent, rotations in this particular case will tend to be lengthened by about 1 to 4 years and output increased accordingly.

Thus, the influence of lower conversion cost per unit of volume with advancing size and age, though possibly small, is perceptible and significant.

Table 4. — Rate of return on extra growing stock as related to average annual timber yield per acre of 10 hypothetical regulated Douglas-fir forests on site III managed for one cut per rotation—assuming that timber value per board foot increases 1/2 percent per year of age

| Rotation (years) | Yield | | | | Growing stock | | | Return on extra growing stock | Return shown in column 9 of table 3 |
|---|---|---|---|---|---|---|---|---|---|
| | Cumulative | Annual per acre | | | Cumulative | Per acre | | | |
| | | Total | | Extra | | Total | Extra | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| | Board feet | Board feet | | | Dollars | | | Percent | |
| 30 | 300 | 10 | 0.10 | -- | 15 | 0.50 | -- | -- | -- |
| 40 | 4,500 | 112 | 1.18 | 1.08 | 266 | 6.66 | 6.16 | 17.5 | 17.3 |
| 50 | 12,400 | 248 | 2.74 | 1.56 | 1,188 | 23.76 | 17.10 | 9.1 | 8.7 |
| 60 | 23,800 | 397 | 4.61 | 1.87 | 3,255 | 54.25 | 30.49 | 6.1 | 5.6 |
| 70 | 35,200 | 503 | 6.14 | 1.53 | 6,785 | 96.93 | 42.68 | 3.6 | 3.0 |
| 80 | 45,700 | 571 | 7.33 | 1.19 | 11,866 | 148.32 | 51.39 | 2.3 | 1.7 |
| 90 | 55,000 | 611 | 8.24 | .91 | 18,507 | 205.64 | 57.32 | 1.6 | .9 |
| 100 | 62,800 | 628 | 8.91 | .67 | 26,670 | 266.70 | 61.06 | 1.1 | .4 |
| 110 | 69,400 | 631 | 9.40 | .49 | 36,292 | 329.93 | 63.23 | .8 | .1 |
| 120 | 75,000 | 625 | 9.79 | .39 | 47,339 | 394.49 | 64.56 | .6 | -.2 |

As for prospective forest reestablishment costs, such as of site preparation and planting or seeding, they tend to influence the rational forest owner to lengthen his rotation (and raise his output) in order to reduce them by postponement. Their effect upon the percentage return from timber growing may be thought of as exerted through the extra annual yield per acre. For example, if the owner anticipates a reestablishment cost of $30 per acre at the end of the rotation, he can reduce this reestablishment cost per average acre of regulated forest by lengthening the rotation, as follows:

| Rotation (in years) | Reestablishment cost (in dollars) per average acre of regulated forest |
|---|---|
| 30 | 1.00 |
| 40 | .75 |
| 50 | .60 |
| 60 | .50 |
| 70 | .43 |
| 80 | .38 |
| 90 | .33 |
| 100 | .30 |
| 110 | .27 |
| 120 | .25 |

When these reestablishment costs are deducted from the total annual per acre yields of column 4 in table 4, the result is as shown in table 5. Percentage returns are raised above those in table 4, and indicated rotations are lengthened—about a year in this case. Again the effect may be small, but it is significant.

What predictions are being made by thoughtful forest owners concerning timber value differentials, and what assumptions are reasonable to propose for the future? The issues regarding changes in unit value of wood with forest age are the sharpest and potentially the most influential.

Table 5. — Rate of return on extra growing stock as related to average annual timber yield per acre of 10 hypothetical regulated Douglas-fir forests on site III managed for one cut per rotation—assuming that timber value per board foot increases 1/2 percent per year of age and that it costs $30 per acre to reestablish a stand after cutting.

| Rotation (years) | Yield | | | | Growing stock | | | Return on extra growing stock | Return shown in column 9 of table 4 |
|---|---|---|---|---|---|---|---|---|---|
| | Cumulative | Annual per acre | | | Cumulative | Per acre | | | |
| | | Total | | Extra | | Total | Extra | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| | Board feet | Board feet | | | Dollars | | | | Percent |
| 30 | 300 | 10 | -0.90 | -- | 15 | 0.50 | -- | -- | -- |
| 40 | 4,500 | 112 | .43 | 1.33 | 266 | 6.66 | 6.16 | 21.6 | 17.5 |
| 50 | 12,400 | 248 | 2.14 | 1.71 | 1,188 | 23.76 | 17.10 | 10.0 | 9.1 |
| 60 | 23,800 | 397 | 4.11 | 1.97 | 3,255 | 54.25 | 30.49 | 6.5 | 6.1 |
| 70 | 35,200 | 503 | 5.71 | 1.60 | 6,785 | 96.93 | 42.68 | 3.7 | 3.6 |
| 80 | 45,700 | 571 | 6.95 | 1.24 | 11,866 | 148.32 | 51.39 | 2.4 | 2.3 |
| 90 | 55,000 | 611 | 7.91 | .96 | 18,507 | 205.64 | 57.32 | 1.7 | 1.6 |
| 100 | 62,800 | 628 | 8.61 | .70 | 26,670 | 266.70 | 61.06 | 1.1 | 1.1 |
| 110 | 69,400 | 631 | 9.13 | .52 | 36,292 | 329.93 | 63.23 | .8 | .8 |
| 120 | 75,000 | 625 | 9.54 | .41 | 47,339 | 394.49 | 64.56 | .6 | .6 |

Assumptions about conversion-cost differentials and reestablishment cost.— As regards increases in unit value of timber resulting from decreases in conversion cost with advancing age and size, past studies show great differentials, but suggest also that the differentials are shrinking in Douglas-fir country and may be expected to become still smaller as time goes on. Brandstorm's work published in 1933 (1, table 46, p. 76), covering the costs of logging and transportation by methods adapted primarily to old growth, shows especially large differentials in the tree-size range from 14 to 24 inches or so, d.b.h. Interpreted for site III timber with $10 stumpage value at 50 years of age, Brandstorm's differentials amount to an increase in value per thousand feet of close to 1 percent annually over the remainder of a rotation. More recent studies (5, 10, 11) point to lower value dif-

ferentials, on account of logging and transportation costs, down to 1/2 percent or a little less per year of age.

If cost studies were extended through the log-conversion plant, so as to reflect stumpage-value differentials in terms meaningful to the integrated forest owner, these differentials would be found somewhat larger than the ones just cited.

On the other hand, all available data and experience on conversion costs relate to an era which differs markedly from the future period with which this study is concerned in that the conversion industry was in continuous process of adapting itself to smaller raw material and was always under some technological disadvantage in handling the new average sizes of the day. It is reasonable to suppose that, in a stabilized young-growth economy, converters will match their methods to their materials in such fashion as to minimize both the absolute and the relative disadvantages of handling small-diameter and short-length wood. Some clue to what the industry may expect is, perhaps, to be found in past cost data for the tree sizes to which converters were well adapted at the time. Thus, Brandstrom's cost differentials for trees in the 30- to 40-inch range, if applied in the size range considered earlier (14 to 24 inches), would represent a per thouannd value differential of less than 1/4 percent per year on $10 stumpage in contrast with the 1-percent contained in the Brandstrom data for 14- to 24-inch trees. On stumpage of higher value, the differential would be less than 1/4 percent, but, on the other hand, it would tend to be pushed up if milling costs were accounted for.

It is assumed in this study that the effects of conversion cost differentials and of reestablishment costs upon the timber-management program are suitably allowed for by adding 1 percent altogether to the value growth percentage of the forest—that is, to the figures such as in column 9 of table 3, based on constant value per unit of measure. This method of making the allowance is admittedly rough. Strictly, the proper allowance will vary with such factors as forest site quality, the owner's guiding rate of interest, the unit of measure to be used, and the costs of conversion and reestablishment in relation to other costs and to revenues. However, the errors are small in comparison to the allowance itself, and their weight in the end result is believed to be negligible.

Assumptions about quality differentials: saw log objective.—As regards increases in unit value of timber resulting from improvement in quality of wood (end-product value) with advancing tree age and size, some wide differences in judgment are to be found among persons who have studied the question. On the one hand are those who believe that logs capable of yielding the larger cuttings with fewer knots will always command a great premium, and that the ideal log of the future, though not conceivably matching yesterday's deep-clear peeler, yet is its young-growth counterpart. For those whose thoughts run in such a vein, the goal of timber management is a relatively long rotation. For them, the ideal management program would include artificial pruning, since Douglas-fir makes such small gains by natural pruning, even in rotations of 100 to 120 years.

At the other extreme are those whose philosophy for the future is that wood is wood and quality, however our standards concerning it may develop over the years, will not be grown into the product but will be manufactured into it mechanically or chemically. This, of course, is short-rotation thinking that provides little if any place for pruning in the silvicultural program. It is a point of view that one expects to find, and does find, in the pulp and paper industry. But it is common also in the mechanical processing industries, conspicuously in veneer and plywood. Here it may seem to be out of place until one reflects that this industry more than any other has been forced to adapt itself to its raw material and has gained confidence in its continuing ability to adapt.

So wide is the range of judgment about future timber quality differentials that two alternative assumptions are made in this study. These assumptions, lying between the extremes outlined above but situated near each end of the range, are termed a saw log objective and a wood objective. The two assumptions can be viewed as the basis for any mixed, intermediate assumption.

The saw log objective assumption is that longrun future values per board foot of timber will not vary with tree age or size on account of end-product quality: The assumption is that a board foot of lumber is a board foot of lumber, so long as it is made from trees 11 inches and larger in diameter utilized to a minimum 8-inch top inside bark and so long as the amount of it is estimated by the Scribner log rule. In other words, the average value per board foot of products made from 30-year-old-trees is assumed to be the same as that from 120-year-old trees. To apply this assumption in this analysis, constant value per board foot is assigned to the Scribner log rule estimate of board feet. This actually results in a slight allowance for increasing value of lumber per board foot lumber tally. For a constant price of $10 per thousand board feet, Scribner log scale, the corresponding stumpage price per thousand board feet lumber tally ranges from $7.50 for 30-year-old timber to $8.97 for 120-year timber. Since International 1/4-inch log rule closely approximates lumber tally throughout a wide range of tree sizes, it can be used as a best estimate of lumber recovery. The slight increase, then, is illustrated in the following tabulation of normal Douglas-fir yields on site III by comparing board-foot International 1/4-inch for trees 11 inches and larger in diameter to an 8-inch top with board foot Scribner under the same utilization standards (6, pp. 27, 66) for the same stand ages:

| Stand age (years) | Total yield, International 1/4-inch (Board feet) | Total yield, Scribner (Board feet) | Price per M, International 1/4-inch, if $10 per M for Scribner (Dollars) |
|---|---|---|---|
| 30 | 400 | 300 | 7.50 |
| 40 | 5,400 | 4,500 | 8.33 |
| 50 | 14,600 | 12,400 | 8.44 |
| 60 | 27,800 | 23,800 | 8.55 |
| 70 | 40,600 | 35,200 | 8.66 |
| 80 | 52,200 | 45,700 | 8.75 |
| 90 | 62,300 | 55,000 | 8.83 |
| 100 | 70,600 | 62,800 | 8.90 |
| 110 | 77,600 | 69,400 | 8.94 |
| 120 | 83,500 | 75,000 | 8.97 |

Although this is only a slight allowance for increase in end-product unit value with age, it is an adequate allowance when compared with published results. McBride (7, 8) found relatively small influence of log diameter on the value per board foot lumber tally of lumber recovered from 8-inch and larger logs. Translated into trees, this influence is still smaller. Matson (5) stated that, without pruning, no clear grades of lumber can be expected from young-growth Douglas-fir up to 100 years of age.

This assumption of constant end-product quality irrespective of tree age and size is believed to place as much emphasis upon conservative management as is defensible in view of the fact that much of yesterday's and today's premium on log size has stemmed merely from the existence of obsolescent but undepreciated plant capacity for converting vanishing categories of timber. The day will come when all such categories have vanished and those that are left can be counted upon to reproduce themselves.

The saw log objective assumption implies that mechanical wood-conversion industry will prove reasonably flexible and fairly adaptable to raw material supplies and will continue in the long run to be a major user of timber in the Douglas-fir subregion. The assumption is substantiated by the fact that the subregion is outstanding among forest areas of the United States in the long life, fast growth, and long-sustained growth of its principal trees. Surely Douglas-fir and its associates will be a prime source of the larger softwood logs required by the Nation, particularly while a great share of its products are various forms of solid wood.

Assumptions about quality differentials: wood objective.—However, there is still ample room for the other assumption made in this study. The wood objective assumption is that longrun future values per cubic foot of timber will not vary with tree age or size on account of end product quality: Wood is wood, measured in cubic feet of sound, straight sections of trees 5 inches and larger d.b.h. to a

4-inch top—i.e., by the Forest Survey standard (6, p. 22). The presumption is that, in the sort of forest economy here implied, wood quality will be related principally to attributes of the tree other than size and age and so will exert little effect upon timber rotations and yields.

The wood objective is one that might well apply if chemical conversion came to dominate forest industry. At the least, the wood objective assumes a high degree of adaptation to raw material on the industry's part. It assumes that the adapting will be paced by the users of wood as fiber: that their technological advantages over the sawyers and slicers of wood will continue in force. It supposes that consumers, too, will adapt themselves to the raw material resource that is easiest for the industry to create and convert.

## Timber Value Trends

A rising trend in the price of most timber products and of stumpage has for a great many years been a prominent feature of the forest economy in the Douglas-fir country. This trend and the expectation that it would continue have undoubtedly had a large influence upon forestry developments. Their influence can be traced in speculation in forest property during the early era and in the subsequent gradual intensifying of protection, utilization, and silvicultural programs of many forest owners. Over the period from 1910 to 1960, the trend in Douglas-fir stumpage prices relative to the general price level (13, table 4, p. 37; 14, table 1, p. 51) was upward at an average annual rate of about 4 percent. These relative stumpage prices are plotted year by year in figure 5. The data are prices paid for National Forest timber sold. This timber declined somewhat in quality and accessibility over the period. For timber of a given description, the upward price trend may well have been steeper.

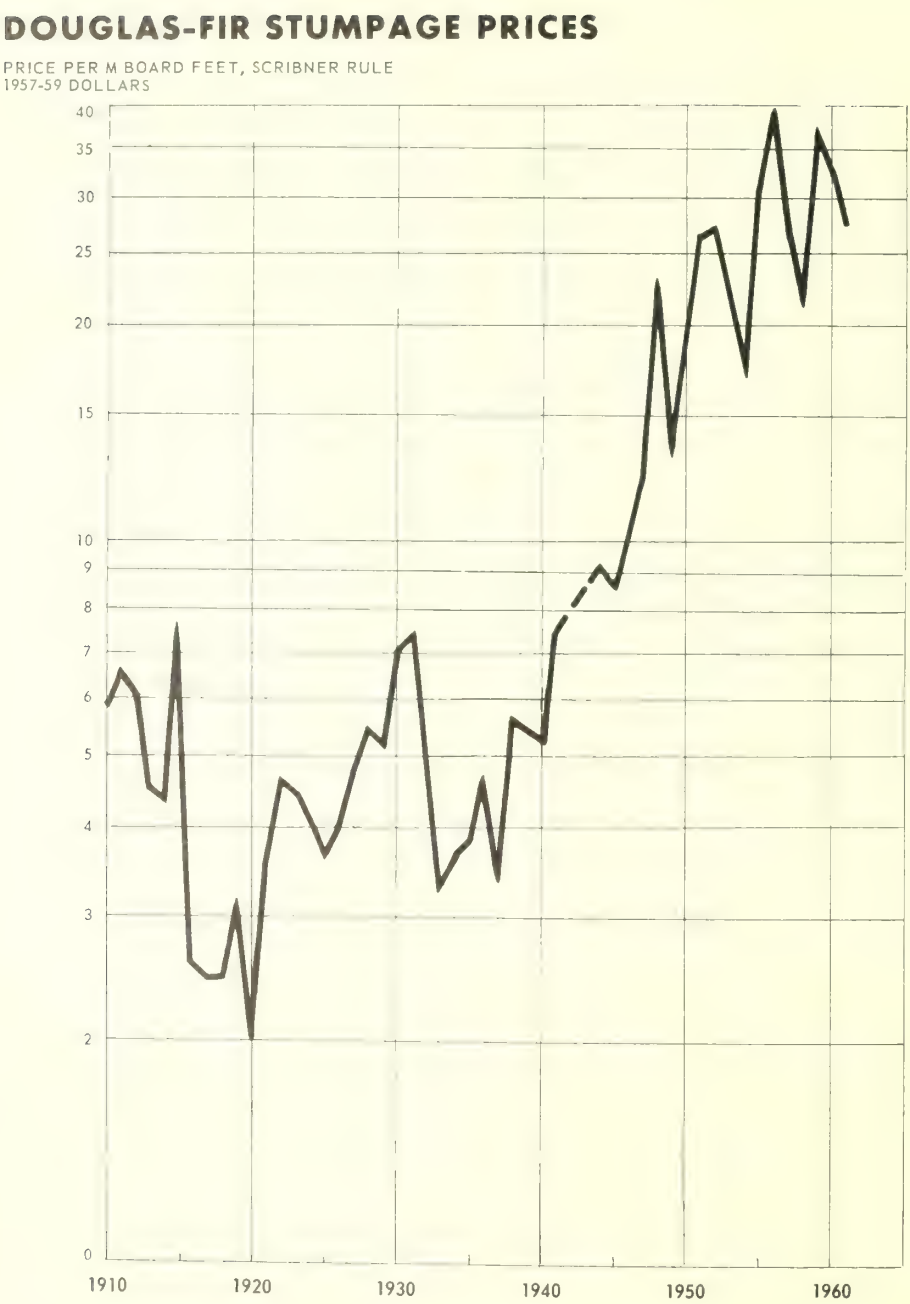


Figure 5.—Douglas-fir stumpage prices in the Douglas-fir subregion, 1910-61, in 1957-59 dollars (adjusted by Bureau of Labor Statistics wholesale price index of all commodities).

A prospective upward trend in timber values influences forest management through the value growth that it represents and through the absolute level to which it promises to push timber value. The first of these influences will be taken up here. The second will be studied immediately afterward under the heading "Timber Value and Management Cost Levels."

Influence of a trend.—The effect of conversion cost differentials upon rotation and yield was illustrated in table 4. The effect of a general trend in value over time is similar, though for a given percentage differential the effect on rotation length is smaller because an upward time trend increases growing-stock investments as well as value growth for each rotation alternative. Thus, the rise in percentage return is dampened, so that the upward pressure upon rotation and yield also is dampened.

Nevertheless, the expectation of a 4-percent or higher value trend can be counted on to wield great influence upon the actions of the forest owner. It has an effect similar to the application of fertilizer to a young-growth forest. But the fertilizer in this case is free—a gift from consumers—and it increases tree increment without the necessity for widening the annual rings. To old-growth timber investments, the value trend lends new vigor. Old-growth stands, even those that are static in respect to net wood volume, become a perfectly desirable investment for the conservative owner when a 4-percent or greater value trend is in prospect. Indeed, as experience shows, he may be glad to hold such stands indefinitely if property taxes allow and if he is not pressed for raw material.

Assumptions about the trend.—The rising stumpage price trends of the past are the result of influences which, though still active today, nevertheless are already in a process of change which may well lead to their disappearance—and, what is more to the point, are already impressing forest owners with their impermanence.

The demand for stumpage presumably is derived from the demands for lumber, plywood, paper, and other forest products. These latter demands have long been rising with national population and income and with the persistence of consumer preferences for wood. Rising demand has been evidenced, in the case of wood-pulp products, by a rising national consumption trend, per capita as well as total. In the case of lumber, it has been witnessed by sustained total consumption in the face of steeply mounting prices.

Growing demands for stumpage have not been met by a like response in supplies. In the Douglas-fir subregion, stumpage supplies receded with the old-growth timber. From the earliest times, this receding, together with the threat of scarcity and the organization of forest properties under deliberately conservative cutting programs—that is, timber management itself—has served to hold down the supply for cutting. Meanwhile, young-growth production did not fill the gap. The major, mechanical conversion segment of wood users, and especially the lumber industry, lagged in its adaptation to raw material. And the supply of young growth was not yet big enough (nor that of old growth yet small enough) to encourage

widespread adaptation. Among the regions of the United States, only the South was seeing a strong resurgence of industry based on young-growth timber.

Thus, during most of its life the wood-using industry of the Douglas-fir subregion has been in process of transition. During industrial transition, when new technology and new firms are coming in to replace the old, basic exhaustible resources that were of high grade under the old regime are almost bound to assume greatly inflated values as the hard-pressed lagging element of the industry fights over them for survival. Old-growth timber qualifies as an exhaustible resource. And during transition the process of substitution draws all timber into the scheme of rising values. Over the past couple of decades, while the plywood industry was increasing its take to about 30 percent of the entire saw log output of the subregion, Douglas-fir log prices were rising more than 3 percent per year relative to all commodities.

The rising trend in stumpage values, compared with the general average of values in the economy, seems likely to continue for some time in the United States, and the Douglas-fir country may be expected to share in this experience. Some rise will take place so long as demands keep edging ahead of supplies. However, for the long run, the likeliest assumption, not to say the most cautious one, is that forest owners will no longer foresee such a trend clearly enough for it to influence their management decisions—that is, they will come to expect stable values. They will see a fair abundance of young-growth timber coming on. They will understand, more fully than today, the Nation's forest-supply potentialities. Thus, much of the speculative element in timber values will be removed. Furthermore, forest owners will expect the consumers of wood products to adapt themselves to the timber supply by changing their scale of preferences and turning to products made from cheaper substitutes.

Today, many forest owners in the Douglas-fir subregion are already viewing future stumpage values with caution. In their long-range management planning, even those who take account of expected continuing general inflation are reluctant to consider a rising trend in the relative price of stumpage. The assumption made in this study is that any outlook for rising relative prices of stumpage will in future exert continuously less influence upon timber management. Where, in the analysis, specific assumptions regarding the price level are required, the levels used are as follows except where stated otherwise: for material of sawtimber size (trees 11 inches or larger, d.b.h., to a minimum 8-inch top) an average of $40 per thousand board feet, Scribner rule, in the terms of figure 5; for smaller material, positive values ranging downward to nominal amounts per cubic foot in 5-inch trees to a 4-inch top in stands having the least favorable composition, volume, and location.

The longrun output of timber that is projected later in chapter 3 will be down if a price less than $40 is assumed in this study.

## Timber Value and Management Cost Levels

Apart from trends, the level of timber values that forest owners and potential owners foresee, in relation to the anticipated costs of growing timber, will have an effect on management programs and timber output. Some of the major management items through which the revenue-cost prospect will influence output are as follows:

1. Land use. Other things being equal, the higher the prospective unit value of timber is in comparison with costs of production, the more forest land will be given over to timber growing, and the more nonforest land will be converted to timber use.

2. Forest administration and protection. The higher the prospective unit value of timber is, the more the forest owner and the community will be inclined to lay out for transportation facilities and other forest improvements, fire control, professional services, and the like.

3. Forest regeneration. The higher he expects the unit value of timber to be, the more the forest owner will be willing to pay for insuring prompt and successful regeneration of superior trees.

4. Forest site improvement. The higher the anticipated unit value of timber is, the more practicable it may become to apply fertilizer to forest lands and to carry out other site-improvement measures.

5. Timber-stand improvement. The higher the prospective unit value of timber is, the greater the incentives are to carry out any weeding, thinning, or other stand-improvement measure promising a deferred return in the form of extra yield.

6. Timber utilization. The higher the current unit value of timber and its products are, the further the forest owner and timber converter will extend their utilization. They will extend utilization to new tracts and within the tract to new trees and parts of trees. They will tend to enlarge the practice of intermediate cutting and to shorten the cutting cycle. And they will be inclined to convert a larger proportion of all harvested material into end products.

Respecting all six of the foregoing management items, higher timber values (relative to costs) tend to exert their influence upon practice in a progression from the most favorable toward the least favorable situations: from good sites into poorer, from easy terrain into more difficult, from the most conservative owners toward the more exploitive, and so on. Through the first five items, wider prospective price-cost margins have the effect of intensifying timber management on all forest holdings. However, the relation of the sixth item, utilization, to management intensity may be somewhat different, depending upon the forest owner's guiding rate of interest. For conservative owners, with a low guiding rate, high timber values may work through the utilization factor to intensify management. But for exploitive owners, high values may simply further the opportunity for and the practice of exploitation.

Of the six management items, the first (land use) and part of the second (roads) will be discussed later under those headings. The rest of the items will be taken up now.

Forest administration and protection.—The key to administration and protection on any forest is access. This, in today's terms, means roads. In terms of the long run, it means the transportation devices of the time, whatever that may be: air or ground systems or some combination. The technology of forest access may be expected to develop in accordance with the opportunities to reduce cost. The greatest reductions in transportation cost may be looked for in outlying, rugged areas. Technological developments may well have the effect of reducing transportation cost differentials between today's easy and difficult areas—that is, of putting all areas more nearly on a par when it comes to access. Any replacement of ground by air systems will surely have such a tendency.

In recent years, the intensified forestry programs of conservative private owners in the Douglas-fir subregion have been paced by road building. These owners have paid for their roads out of the proceeds from relogging of cutovers, prelogging and harvest cutting of mature timber, and the anticipation of thinnings and final cuts from other areas. And the roads have been generally justified, too, by their role in safeguarding timber values against damage and in permitting the salvage of damaged timber. Road development has been accompanied by great intensification of forest fire control and other protection measures. And the staff of professional foresters and other forest workers has been enlarged in keeping with greater forestry accessibility and the new opportunities for management thus created. Today's price-cost ratios and price-cost anticipations have been ample to stimulate these actions by conservative private owners.

More exploitive private owners, with their higher rates of discount, are less strongly motivated to develop their forest administration and protection where yields are far in the future. On the other hand, their tracts are generally more accessible to begin with because of size and location. And their interest in immediate returns has encouraged them to build forest roads wherever necessary for capturing current values.

Public forest owners hold most of today's highly inaccessible forest lands. Some of these lands present excessive difficulties for administration and protection in light of current technology. However, even at present prices and costs, such is the public interest in forest values besides timber and in developing the public forests as examples of conservative management that most of the difficult areas are due for intensive development as soon as appropriations or cutting programs or the solving of right-of-way problems permit. And in the long run, it seems fair to assume that all areas will be thus developed, even in the absence of any further price-cost incentives.

For the long run, it is assumed that transportation will be such as to permit ready and relatively equal access to all acres of commercial forest. It is assumed that public and private forest protection efforts, coupled with excellent opportunities

for salvage, will reduce timber losses to a negligible level. And it is assumed that the timber management appropriate to each class of forest owner will be supported by technical foresters employed by the owner or available to him from public sources.

Forest regeneration.—So far as the value of output in relation to cost is concerned, management decisions respecting forest regeneration center around the choice between natural and artificial regeneration. The latter method has primarily three points of advantage: first, it may reduce or eliminate delay in starting a new crop; second, it may insure establishing just the species and strains of trees that are wanted; third, it may insure the best spacing of stems without the necessity for very early treatment of the stand. The rational forest owner can be expected to use artificial regeneration wherever he can foresee that these advantages will outweigh the extra costs of planting or seeding.

For example, considering the costs of artificial regeneration and the costs of treating young natural stands, suppose that artificial regeneration requires an outlay $10 (1947-49 basis) greater per acre than that required by natural regeneration. But suppose that, as a countervailing influence, the yields from natural stands under a regime of intermediate cutting fall 10 percent short of plantation yields.

Then take the case of the conservative owner of average site (index 140) Douglas-fir. As will be developed in chapter 3, this owner's best program is an 80-year rotation with a prospective annual per acre yield of about 580 board feet, Scribner rule. If artificial regeneration involves an extra cost of $10 per acre, its extra cost per acre per year under an 80-year rotation is 12.5 cents. At the same time, its prospective 10-percent saving of yield is 58 board feet per acre per year. At $40 per thousand, this saving amounts to $2.32. Even if the entire saving were postponed for a full rotation, which is an overly conservative supposition, the current value of it would be $2.32 divided by $1.03^{80}$ or 21.8 cents per acre per year—more than enough to justify the 12.5-cent cost.

Similar figuring on the basis of the same assumptions leads to the conclusion that the conservative owner has even clearer justification for artificially regenerating good site (index 170) Douglas-fir land with its higher yield, shorter rotation, and greater risk of hardwood invasion. On poor sites (index 110), despite lower yield and a longer rotation, artificial regeneration still has the advantage so long as the probable delay in getting natural reproduction is as much as 3 or 4 years. On upper slopes, where even longer rotations are indicated, the great advantage of assuring stands of red or noble fir and white pine in preference to mountain hemlock again gives the edge to artificial regeneration.

The intermediate forest owner with a 6-percent guiding rate of interest is found occupying a marginal position between natural and artificial regeneration when the foregoing assumptions are used. But when it is considered that extra yields of artificial stands may well commence with the earliest commercial thinnings and that the yield advantage of such stands over natural stands will probably be enlarged by innovations in the area of forest genetics, the intermediate forest

owner, too, becomes a canddiate for the practice of planting or seeding so long as there are serious risks of delay of more than a very few years in getting natural regeneration.

It therefore appears that the economic climate of the future will be highly conducive to prompt forest regeneration. Because of the preponderant economic advantage on most lands, laws requiring prompt regeneration will probably remain in force and will bring about conformity in the doubtful cases, the poorest sites and the holdings of exploitive owners.

However, at such levels of stumpage value as have been analyzed here, the exploitive owner with a 12-percent rate of discount can be expected to have difficulty justifying forest seeding or planting so long as alternatives are open to him for conforming with regeneration requirements of the State forest conservation laws. Artificial regeneration may recommend itself to him on the best sites and in cases where a plantation has special values in his eyes or where his establishment costs are exceptionally low. But typically he will rely on natural regeneration. He will be glad to sacrifice some prospective timber yields in order to escape the immediate cost of getting regeneration.

In figure 6, the possible response of the exploitive forest owner to stumpage price in the long run is traced out in graphic form. The effect of price upon his regeneration method is interpreted in terms of annual per acre output on each of the four classes of conifer sites mentioned earlier. The basic yields on these sites are those derived in chapter 3 of this report and given in table 15. Figure 6 illustrates the relationship of a stumpage price range from $40 to $100 (1957-59 basis) per thousand board feet for one class of owner. Take as an example good site, where regeneration method is especially sensitive to prices because the possible gains from planting are so great. At the lower end of the range, the assumed stumpage price of $40 would justify a relatively slight use of artificial (rather than natural) regeneration, and the average annual yield per acre is estimated at 424 board feet (table 15). At the upper end of the range, the greater interest in artificial regeneration that can be expected is estimated to promise an average yield of about 450 board feet. These average yields are for the good site forests of all exploitive owners taken as a group.

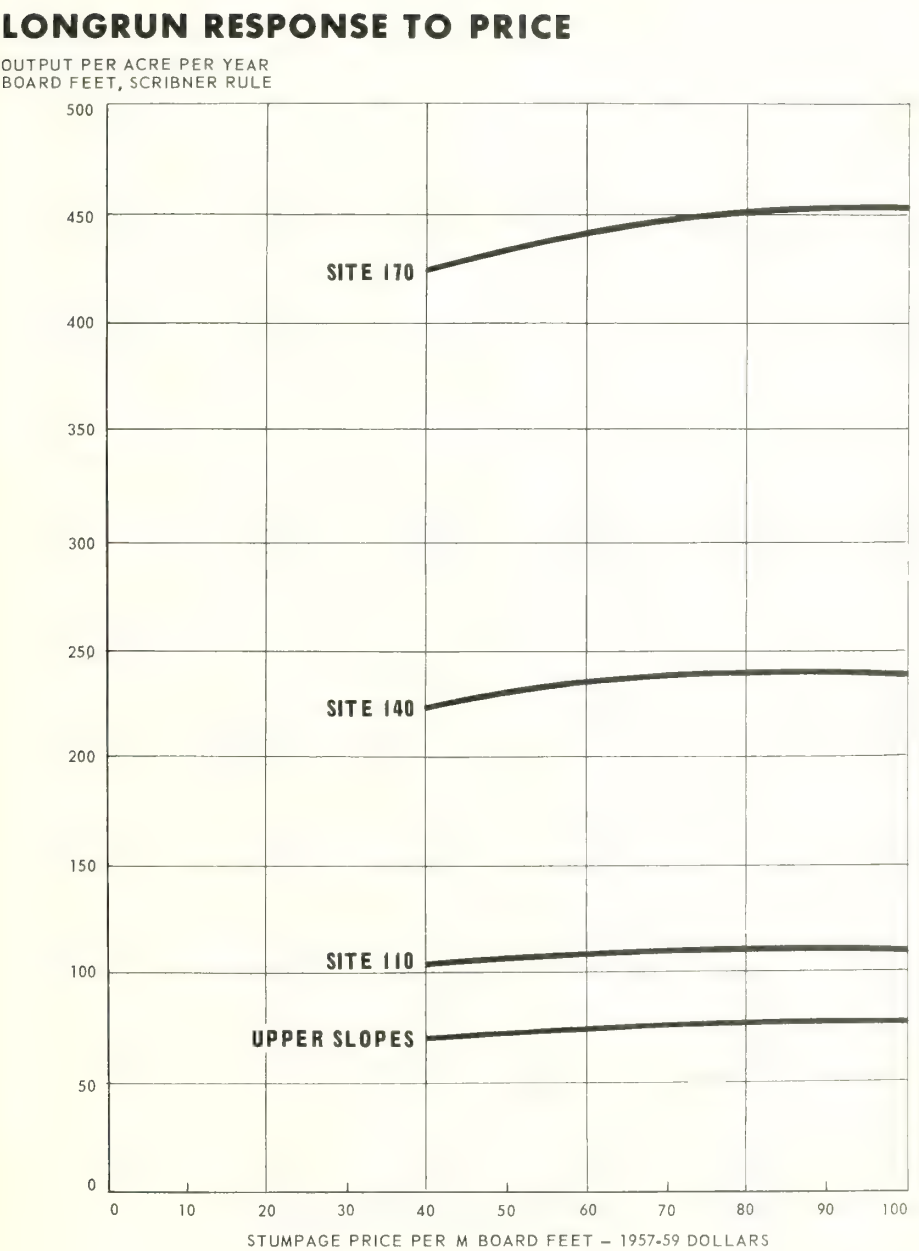


Figure 6.—Estimated longrun relation of timber output to prospective price level arising from regeneration practices on holdings of exploitive owners.

Forest site improvement.—The practice of forest site improvement, notably the application of chemical fertilizer to forest soil, may have a great potential influence upon timber management and timber output. In view of this possibility and despite the fact that supporting data are scant, it is essential in this analysis to take some account of fertilizers. Assumptions will therefore be made about the physical effects of fertilizers, and the calculation of economic influences will be based on these assumptions.

If some of the current estimates about benefits of forest fertilizers are near the truth, then it is just a question of time until fertilizers come into general use, and timber yields can be expected to increase greatly as a result. For example, it is sometimes estimated that with fertilizer as much timber can be grown in 50 years as would grow without it in 70—that is to say, that fertilizing can raise the annual per acre yield 40 percent. For middle site Douglas-fir under conservative management, such an increase would amount to more than 200 board feet per acre per year.

The assumptions to be used here are more cautious. A fertilizer program is assumed that calls for light applications at 5-year intervals, at a cost per application of $10 (1957-59 basis) per acre. It is supposed that such a regime will increase the yield on high Douglas-fir site (index 170) by 10 percent, on medium site (index 140) by 17 percent, and on low site (index 110) and upper slopes by 35 percent. These percentages are chosen so as to represent an absolute increase in yield of about 100 board feet per acre per year on intensively managed Douglas-fir land—a little more than this on low sites, with their greater potentialities for improvement, and a little less on high sites.

The capitalized per acre cost of the assumed program is:

$$F + \frac{F}{(1+i)^f - 1}$$

where F is the per acre cost of one application, F is the frequency of application in years; and i is the forest owner's guiding rate of interest in decimals.

In a regulated forest that produces an annual harvest of thinnings and final cuts, if the extra yield of a fertilizer program augments the harvest gradually and in equal yearly increments during the first rotation, and thereafter is harvested in full, then the capitalized per acre value of this extra yield is:

$$\frac{I}{Ri^2} \cdot \frac{(1+i)^R - 1}{(1+i)^R - 1}$$

where I is the value of the full extra yield per acre per year and R is the rotation length in years.

For illustration, take the case of the conservative owner of an intensively managed Douglas-fir forest on medium site. In the absence of a fertilizer program, his rotation is 80 years, and his annual timber output is about 580 board feet per acre. Considering his 3-percent guiding rate of interest, his capitalized cost of fertilizing according to the assumed program is $72.89 per acre. The

extra yield anticipated from the program is 98 board feet per acre per year. If the capitalized value of this extra yield per dollar of stumpage price (per thousand board feet) is computed by taking I in the expression as equaling 9.8 cents, the result is a capitalized per acre value of $1.271. One concludes, then, that in order for the assumed fertilizer program to be financially attractive, stumpage would have to be worth at least 72.89 divided by 1.271, or $57.35 (1957-59 basis) per thousand board feet, Scribner rule.

The minimum prospective stumpage value required to make the assumed fertilizer program attractive to each class of forest owner on each of four forest site classes is given in table 6. These values are all calculated for the hypothetical program that has been outlined. The forest rotation lengths and timber yields used in the calculation are those derived and explained in chapter 3 of this report and set out in table 15. It will be observed that fertilizing is the best bet on average Douglas-fir sites conservatively owned. Under conservative ownership, high sites offer lesser attractions because of the lower extra yields assumed, and low sites lose out because of longer rotations. Under intermediate and exploitive ownership, higher interest rates shorten the rotation and place the fertilizer program at a successively greater disadvantage. At a high interest rate, rotation length becomes the controlling element in the minimum stumpage value.

Timber-stand improvement and utilization.—The current and prospective level of stumpage values in relation to costs may be expected to bear directly on the attractiveness of all forms of timber-stand improvement carried out by harvesting or removing selected stems from the forest. The measures involved range from brush control in very young stands to the last commercial thinnings in stands nearing rotation age.

Table 6. — Minimum prospective stumpage value per thousand board feet necessary to attract a forest owner to undertake the assumed fertilizer program by class of owner and conifer site class.

| Site class | Conservative owner | Intermediate owner | Exploitive owner |
|---|---|---|---|
| | | 1957-59 dollars | |
| Douglas-fir site 170 | 62 | 115 | 300 |
| Douglas-fir site 140 | 57 | 123 | 373 |
| Douglas-fir site 110 | 59 | 138 | 420 |
| Upper slopes | 86 | 190 | 661 |

Measures that yield no immediate return in the form of merchantable wood derive their justification from prospective increases in output. For given increases and periods of waiting for them, a measure is justified if anticipated timber values are high enough in relation to treatment costs and if the interest rate is low enough. Measures that do yield an immediate return must pass the same test. However, the treatment cost in this case is rightly figured net of the immediate return, and consequently the latter, is high enough, may decide the issue in favor of the treatment, irrespective of the delayed extra yield so long as there is any. That is to

say, a "commercial" treatment of the stand, such as a commercial thinning, may be undertaken regardless of interest rate and prospective price.

Thus, in an era where stumpage values follow a horizontal trend, such as is here assumed for the long run, the level of value may exert its principal influence upon stand improvement practice, not so much through its effect on prospective value yields as through its effect on current wood utilization and on the question whether the improvement measure contemplated is a commercial treatment. It is assumed that at a $40 sawtimber price the relation of wood values to conversion costs will permit utilization of all principal tree species at least to a d.b.h. of 5 inches and an inside bark top diameter of 4 inches. The stand-improvement regime expected under these circumstances, and the accompanying timber yields, is described at the beginning of chapter 3.

At prices higher than $40—costs remaining the same—there is negligible room for increases in board foot yield. Cubic foot yield under a wood objective will be somewhat more strongly correlated with price through the influence of utilization.

## Forest Taxation

The next timber management influences to be considered are property and income taxes. Discussion of inheritance taxes, which are an intermittent and relatively remote item of cost, will be postponed until the subject of forest ownership is taken up.

Property taxes: absolute amount.—Property taxes, like any cost item, may wield an influence upon a forest owner's timber management in two different ways. First, the absolute amount of the tax may affect his decision about owning the land or using it for timber production. Second, if the land is used for timber production, the relative amount of the tax levied when a certain management program is in effect (as compared with what the levy would be under some other program) may sway the owner's management decisions. Through both types of influence, forest property taxation may affect timber output.

As regards the absolute amount of the forest property tax, any tax that is high enough to extinguish the value of the land for forest use or depress it below the value for any other use—that is, to reduce the capitalized value of the forest property below its liquidation value—is confiscatory in the sense that it may lead the owner to liquidate the timber and either abandon the land or shift it to another use. For example, for the owner who uses a 4-percent interest rate and follows a 60-year rotation (table 3), gross timber yield ($3.97) capitalized at 4 percent is about $100 per acre. Timber liquidation value (col. 7) is about $50. If taxes and other costs amount annually to more than about 4 percent of the difference, or $2 per acre, they are confiscatory.

Short of confiscation, rising taxes reduce land values and put a hardship upon the current owner. They heighten the risks of forest management and raise the owner's guiding rate of interest, altering his program of output accordingly.

High taxes that are not confiscatory and are not expected to rise may become capitalized into land values and have negligible influence upon timber management. This is the state of affairs assumed for forest property taxation in the Douglas-fir subregion in the future, so far as the absolute amount of taxation is concerned.

Property taxes: relative amount.—With regard to the relative amount of the tax on a forest property under one management program as compared with another program, the influence at issue is that of changes in the amount of the tax per acre arising from changes in assessed value of the property, irrespective of changes in tax rate. There are two kinds of change in assessed value, with quite different effects upon timber management and output.

First, assessed value of a forest property may be changed in accordance with some change in the property that has not been planned or anticipated by the owner. For example, the assessment may be raised because of unexpected monetary inflation or lowered after an unavoidable forest catastrophe. Such changes in assessed value have no effect upon an owner's timber management or output because he can neither cause them nor escape them by altering his program.

Second, assessed value of a forest property may be changed in accord with the planned or foreseeable changes in the property. For instance, the assessment may be raised from year to year with increases in property value because of unharvested timber growth or lowered with decreases in value because of cutting. If a forest owner expects assessment changes of this kind, the expectation may influence his timber management because he can control the changes by means of his management practices. That is to say, there is a way for him deliberately to escape some of the tax, and he may be expected to take advantage of it.

To illustrate the point, consider again the Douglas-fir property of table 3 and the owner who has a 4-percent guiding rate of interest. If the property is assessed in the first manner described, so that the amount of the tax is essentially fixed in relation to the owner's management alternatives, then the tax is neutral toward management, and the timber program is the one previously indicated: to follow a 60-year rotation and grow about 400 board feet of timber per acre per year. On the other hand, if the property is assessed in the second manner described, so that the amount of the tax will vary directly with property value—i.e., with growing stock and growth—then the tax is not neutral: The tax rate is, in effect, subtracted from the rates of return in column 9, and the owner tends accordingly to follow a shorter rotation and produce a lower output, reduce his property value, and thus escape part of the tax.

Time bias in property taxation.—The feature of a property tax that leads to effects of the second kind is sometimes termed time bias in recognition of the fact that it stems from the manner in which the tax changes over time. A time-biased property tax necessarily tends to discourage forest conservation. It is time bias which has been mainly responsible for giving property taxation a bad name in forestry circles. Along with the absolute amount of the tax, time bias arising out of assessment practice (and not the annual feature of the taxation) is the crux of the so-called forest property tax problem.

The assumption made in this study is the same one made by optimistic forest owners in the Douglas-fir subregion: that inequities in the forest property tax, both in the amount of the tax and in its bias, will in future be discovered and eliminated; that procedures will be established for making the property tax neutral toward forest management.

Income taxes.—Unlike property taxes, income taxes tend generally to favor forest conservation. For the taxpayer, escape from the property tax lies in the direction of reducing his property: increasing immediate timber output at the expense of output later. But escape from the income tax lies in just the opposite direction: curtailing immediate timber output and income, accumulating the growing stocks, lengthening the rotation, and thus establishing conditions for ultimate higher yields.

Beyond the influences of any income tax upon timber management are the specific effects of the Federal tax, with its provisions regarding the treatment of long-term capital gains. One of these effects is to encourage the forest owner to incur silvicultural expenses that may be charged against his ordinary income. Another is to stimulate forestry investments in general because of the favorable treatment their revenues from timber will receive. The result is to favor an increase in the timber output of private forest owners, particularly in the long run. The effects of the Federal income tax law upon forest practices are most noticeable in the case of large-scale owners, both individual owners with upper-bracket income and corporate owners with wood-processing enterprises.

It is assumed for the purpose of this analysis that the features of the Internal Revenue Code will be retained.

## Land Use

Up to now, this review of the influences upon timber output has dwelt on the subject of the timber management program—the practices followed on an owner's commercial forest lands. The review turns now to more general influences upon output: first, land use, in determining the entire extent of the commercial forest in the Douglas-fir subregion; and second, the ownership of this forest, in affecting the degree of conservation or exploitation to which the resource as a whole is subject.

Since the manner in which land use and commercial forest ownership affect timber output will be obvious, the discussion is confined to assumptions about the future status of these influences. Attention is directed to the year 2000. An effort is made to foresee some of the changes in land use and ownership that are most likely to come about in the intervening four decades. Where the trend of events is a major issue, a principal assumption and alternative assumptions are offered so that their effects upon output can be compared.

In the long run, still further shifts in land use and ownership are inevitable. However, it is believed that the general character and direction of longrun changes will reveal themselves within four decades and that no great purpose would be

served by attempting to project the trends beyond that period. Consequently, the land use and ownership assumptions for the year 2000 will be taken as applying both to the transition era and to the long run.

Consider now the use of the 35 million acres of land in the Douglas-fir subregion. In the decade of the 1950's, 83 percent of this land was in forest use; 73 percent (25-3/4 million acres) was commercial forest, suitable and available for timber production (table 7). Of the noncommercial forest land, amounting to 3-1/4 million acres, about two-thirds was reserved as National and State Parks, National Forest wilderness areas, and other tracts permanently or temporarily withdrawn from timber use; one-third was classed as noncommercial solely because of low timber productivity.

Lands other than forest lands amounted to 6 million acres, or 17 percent of the total. Nearly two-thirds of these nonforest lands was in farms. The remainder was in towns or other residential or industrial areas, in roads and rights-of-way, and in miscellaneous nonforest uses.

Table 7. — Major uses of land in the Douglas-fir subregion, decade of 1950's

| Use | Thousand acres | Percent |
|---|---|---|
| Forest: | | |
| Commercial | 25,766 | 73 |
| Noncommercial: | | |
| Reserved | 2,301 | 7 |
| Nonreserved | 980 | 3 |
| All noncommercial forest | 3,281 | 10 |
| All forest | 29,047 | 83 |
| Nonforest: | | |
| Farm, pasture, and range | 3,968 | 11 |
| Other nonforest land | 2,085 | 6 |
| All nonforest land | 6,053 | 17 |
| All land | 35,100 | 100 |

What shifts in these acreages is it reasonable to postulate for the year 2000? Of the many alternative land uses, the seven discussed below are believed likeliest to have a measurable impact on timber production. Other land uses—such as military reservations, airports, and summer home sites—were considered but not included for analysis, primarily because their net impact was expected to be negligible. Possible interchanges will be considered between forest land available for timber growing and (1) forest land reserved for recreational use, (2) towns, (3) open farmlands, (4) roads, (5) power sites and rights-of-way, and (6) municipal reservoirs. Thought will also be given to (7) any lands, now classed as commercial forest, which are marginal because of precipitous terrain or very low site—lands whose contribution to the wood basket may therefore prove to be negligible. In this study, such lands are designated as "marginal commercial forest lands."

Recreational areas.—The areas considered here include under the multiple use concept: (1) what will be termed "vast areas," undeveloped tracts outside the boundaries of dedicated wilderness and wild areas, but formerly classified as limited areas, or presently as primitive areas, pending study and reclassification; (2) "developed areas," consisting of camp and picnic grounds; and (3) "protective strips" along roads and streams.

Except for dedicated wilderness and wild areas, it is assumed that there will be at least some logging of most multiple use areas having recreation designated as a dominant use, just as there will be other types of multiple use, including recreation, on other areas where timber production is designated as a dominant use. The actual pattern of use on any specific area will, of course, be determined by current policy and regulations, for example, as spelled out under the 1962 High Mountain Area policy statement.

The future need for and extent of vast recreational areas is a major issue in the West today. The importance of the issue to the subject of timber production in the Douglas-fir subregion is plain. Such areas range from several thousand to several hundred thousand acres each. Often they contain much productive forest land, so that an increase in their numbers can significantly affect timber output.

The type of vast area to be considered here is National Forest land which has been temporarily withheld from commercial timber use pending studies of its potentialities for recreational use. In the 1950's, there were more than 700,000 acres of such land in the subregion. The studies of these lands will not be completed for some time. Meanwhile, the principal assumption made here on the basis of a review of inventories of these lands, a large proportion of which appears to be well suited to timber growing, is that half of them will ultimately be dedicated to recreation as a special use and half of them made available for timber growing as the primary use.

However, the reserving of forest land for recreation is a sharp issue with an uncertain outcome. On the one hand, the demands for forest recreation are great and growing. On the other, national tastes in outdoor recreation may well shift away from vast, single-use forest areas and thus cooperate with the rising demands for timber-growing land. Consequently, two alternative assumptions are made here for later testing. They are liberal, contrasting assumptions: (1) An additional 1 million acres of National Forest lands will in the long run be taken from the commercial category and set aside primarily for recreation—over and above the recreational acreage allowed for in the principal assumption; (2) one million acres of forest land counted as reserved mainly for recreation in the principal assumption will instead be available without restriction for timber growing. A million acres represents about 4 percent of all today's commercial forest land in the Douglas-fir region. But since the sites involved are below average, the fraction of timber output represented is smaller than 4 percent.

The next type of recreational land to consider is the developed area, the camp or picnic ground.

For the National Forests, it has been estimated that by the year 2000 the acreage requirement for developed areas for the United States as a whole will be about eight times what it is today. It is assumed that somewhat this same ratio applies in the National Forests of the Douglas-fir subregion and that 124,000 acres of currently commercial forest land will be reserved for camp and picnic grounds during the next four decades.

For State-owned lands, general forecasts and plans of the park departments suggest the assumption that 84,000 acres of commercial forest will be set aside as developed areas. For other public lands, mainly county and municipal lands, no allowance is made for shifts on account of developed areas. Apparently most of the prospective recreational developments in this case will be on nonforest land, so that forest acreage requirements will be negligible.

For private forest lands, it is again assumed that no allowance need be made for the reservation of developed areas. It is true that a few of the larger wood-using concerns are now providing picnic and campgrounds and that this practice may well be extended. But it is doubtful that such areas will be permanently located. It is likely that they will be rotated to avoid damage to trees and soil. Timber production is the source of these companies' livelihood, and nonrevenue-producing land uses may be expected to remain secondary and not be allowed to interfere seriously with the growing of timber. The picture would change, of course, if forest recreation were on a pay-as-you-go basis.

Finally, there are the protective strips along roads and streams. A considerable mileage of such strips has been reserved in the past, especially by the public landowners. In the future, however, it is expected that reservation policies will be modified. Further wholesale withdrawals are unlikely. Probably new withdrawals will be made only where scenic values are dominant. The resulting subtractions from commercial forest may be at least counterbalanced by sanitation and salvage cuttings in many of the protective strips. It is therefore assumed that no allowance need be made for further reductions in potential timber output on account of such strips.

Urban lands.—Current changes in the acreage of urban land show the results of at least two contrarary influences. On the one hand, there is the phenomenon known as urban sprawl, a determined flight of families to the suburbs and the establishment of "bedroom" communities. On the other hand, families are returning to the city to escape the higher cost of suburban services, added expenses such as that of owning two cars, and the loss of time in commuting. It is quite likely that, in the next few decades, cities will absorb expected population increases not so much by further sprawl as by filling in vacant spaces within city limits, using the extensive areas between suburban developments and redeveloping or renewing old, rundown neighborhoods to provide multiple-family dwellings in an attractive setting. Urban expansion will impinge on other land uses, mostly the farm uses.

It is assumed that the commercial forest use will not be significantly affected within the coming four decades.

Open farmlands.—Farms in the Douglas-fir subregion will be called upon for increasingly large outputs as time goes on. Probably there is a great deal of forest land in the subregion that is suitable for farming. However, there is good reason to believe that larger farm output between now and the end of the century will not be gained at the expense of the forest: that no allowance need be made for shifts from commercial forest to farm use.

Farm acreage in the subregion reached at least a temporary peak in 1950 and is now declining in all districts except the Southwest Oregon (fig. 7). Indications are that there, too, a decline will soon commence. What is happening is that improvements in agricultural technology are making it possible to grow heavier crops on the best lands and are rendering many of the poorer lands submarginal, even in the face of rising demands. Farms are being abandoned in agricultural fringe areas bordering the forest zones. On other farms, owners are doing some forest planting—on their own initiative or with encouragement from the Government.

Trends toward farm contraction may not continue indefinitely, but if they are reversed, there will still be a large acreage of abandoned fringe lands to reoccupy before any net encroachment upon today's commercial forest becomes necessary. The fringe lands will also act as a cushion to absorb, directly or indirectly, the farmers that may be displaced from urban zones.

Roads.—Even a casual observer of the forest economy in the subregion will note that roads must account for a significant reduction in commercial forest area. Two classes are involved in this reduction: (1) forest highways, either State or Federal, which cut through forested lands, and (2) all other forest roads, including county roads and roads constructed specifically for forest purposes such as logging, silviculture, and protection.

As for forest highways, the east-west highways across the Cascades are the ones that take the most forest land at present. Some of the north-south highways also cut through forest land, but their impact is not as great since they follow the valleys. Nearly all the feasible cross-State routes are established. Expected changes during the next four decades amount to realigning present highways, eliminating curves, and perhaps widening some stretches. Eliminating curves and shortening distances are expected largely to offset the taking of additional land in widening rights-of-way, so that the net impact of changes on commercial forest land is expected to be negligible.

As for forest roads other than highways, this use of land will probably have a major impact on the acreage of commercial forest. In fact, it is expected to account for the biggest reduction in all classes of forest ownership in each of the three districts. The reduction will come from two sources. First, the surveyed acreage of commercial forest, such as that given in table 7, includes all rights-of-way less than 2 chains wide. That is to say, forest highways have been deducted from the acreage figures, but the present network of forest roads less than 2 chains

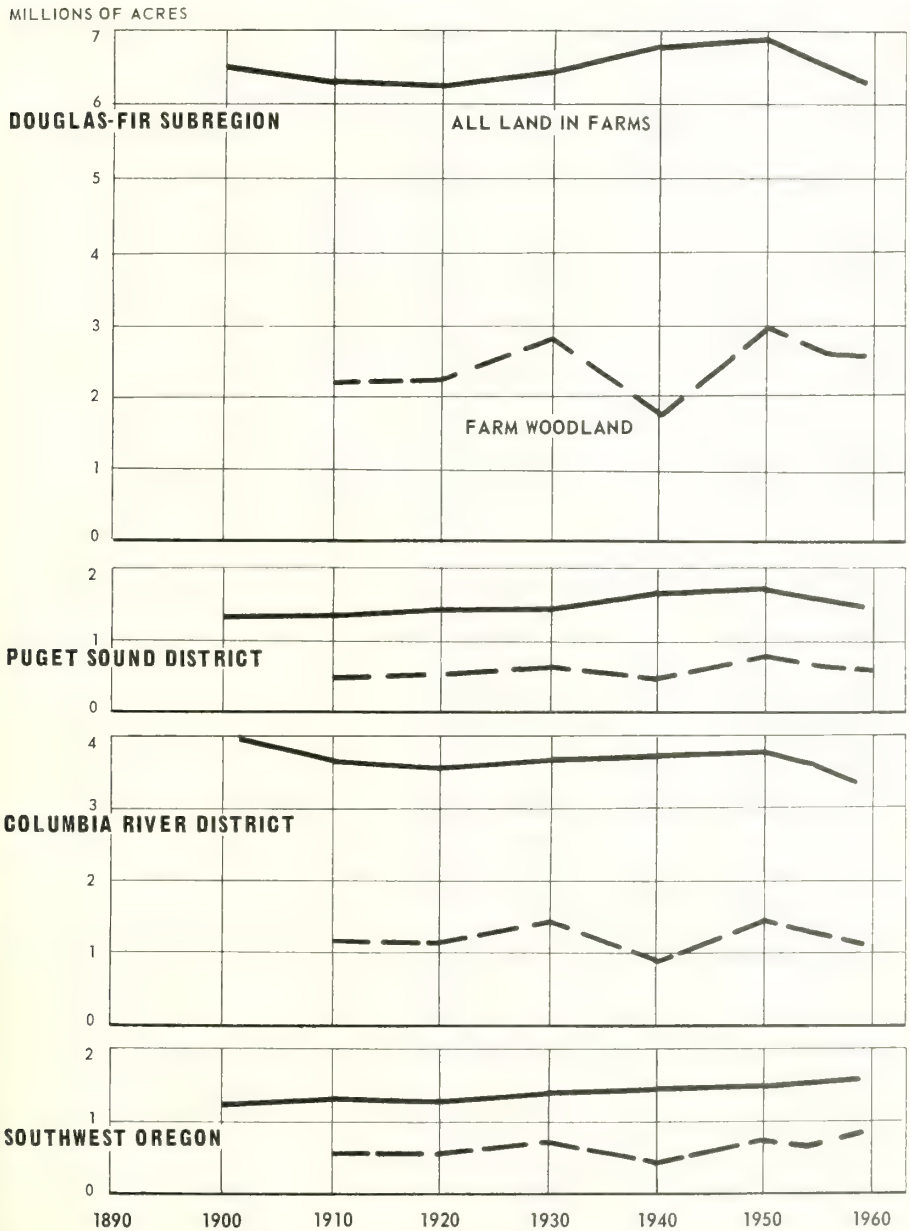


Figure 7.—All land in farms and farm woodland in the Douglas-fir subregion and its three districts, 1900-59. (Basis: U.S. Census of Agriculture. Farm woodland acreages for 1940 are inconsistent with other data in the series because of the forest-land definition used in the 1940 census.)

in width has not been subtracted and must be taken out to arrive at a net figure. Second, the present network of forest roads an all lands except the small private holdings is not adequate for the sort of management expected to be in effect by the year 2000. Present density on all but a few of the most intensively managed lands probably does not exceed 1-1/2 or 2 miles of road per square mile of forest land. In this study, it is assumed that a density of at least 5 miles of road per section will be reached.

In computing how much land will be taken for forest roads, an average right-of-way width of 55 feet is assumed. However, it is assumed that not all the right-of-way will be lost to timber production, since crowns and roots of trees will extend into it. It is estimated that crowns and roots will be able to make use of 10-foot strips on each side. On this basis, the subtraction of commercial forest land on account of roads comes out to 845,000 acres for the subregion as a whole.

Power developments.—Another type of withdrawal that is expected to have a noticeable impact on the subregion's timber production potential is power development, including dam sites, reservoirs, and powerline rights-of-way. With the big upsurge in the building of Federal projects during the last 20 years, a considerable amount of timberland has been inundated. And after Bonneville Dam was finished in 1938, a network of transmission facilities was begun that now accounts for the withdrawal of at least as much timberland as has been taken by reservoirs.

Bonneville Power Administration estimates that by about 1970, all economically feasible major dams and reservoirs will have been completed in western Oregon and Washington. These installations probably will not take so much land as did those of the past 20 years. It is expected that other power sources, such as atomic energy, will then be more economical than remaining hydroelectric possibilities. If all the prospectively feasible dams are built, the resulting additional withdrawals of commercial forest land will amount to possibly 30,000 acres. Most of this land will be in the Columbia River district. Very little will be in the Southwest Oregon district.

Municipal reservoirs.—This topic concerns not watershed lands generally but only the lands inundated by reservoirs. Municipal watersheds today are in many cases used for timber as well as for water production, and it is assumed that in future the means will be found for carrying on the two uses together with negligible interference.

Reservoirs for municipal water supply account at present for only a very small reduction of commercial forest area, probably not more than 5,000 acres. Future needs in the subregion up to the year 2000 should not require more than six times the present acreage, even allowing for greater per capita use of water as well as for population increases. The economics of building storage reservoirs in remote locations and of bringing water to population centers may well become increasingly questionable. The cost of the necessary facilities will probably compare less and less favorably with other means of obtaining water, such as purifying river water and desalting sea water.

Marginal commercial forest lands.—Included in the current inventory of commercial forests is a considerable acreage of very rough, low-site land, the timber potentialities of which are highly uncertain. In the interest of caution, this marginal commercial forest land, estimated at 139,000 acres for the whole subregion, is excluded from future commercial forest estimates. The excluded lands are believed to fall almost entirely in three classes of holdings: National Forests, other Federal lands, and large private holdings.

Land use in relation to timber value.—The estimate of future commercial forest-land acreage implied in the foregoing assumptions about alternative land uses is meant to be valid at a stumpage price of about $40 per thousand board feet. At lower prices, and certainly at very low prices, larger subtractions from the commercial forest column can be expected on account of most of the alternative uses. What is of greater interest in this study, the longrun expectation of higher timber prices would probably result in some land use changes in favor of timber growing. The likeliest source of new timberlands would be the less productive farms of the subregion. A review of the acreages involved by type and size of farm leads to the estimate that, other things equal, a timber price expectation of $100 (1957-59 basis) per thousand board feet would bring into timber use no more than 750,000 acres of farmland. Nearly all this shift in land use would take place in the Puget Sound and Southwest Oregon districts: close to four-tenths of it in the former district and six-tenths in the later.

## Forest-Land Ownership

Attention is shifted now from the general topic of land use as a determinant of future timber output to the more specific subject of commercial forest land and its ownership. How forest ownership can influence timber output was given some thought earlier in chapter 2. Here, the questions to be considered are the present ownership of commercial forest land and the probable future ownership of the land that will then be commercial forest. In assumptions about the future, the year 2000 is again used as the date of reference.

A major simplifying assumption to be made is that, apart from such changes as will be caused by shifts in land use (primarily in connection with roads and reserved areas), there will be no changes in the public ownership of commercial forest land. That is to say, it is assumed that there will be no net transfers of commercial forest among public owners or between them and private owners. Consequently, attention will be devoted mainly to the classes of private forest owners—their holdings today and the changes that may take place among them in the future.

In the Douglas-fir subregion as a whole in the mid-1950's, private owners held about 13.3 million acres of commercial forest land, slightly more than half of the 25.8-million-acre total. Of the private commercial forest, almost half (46 percent) was in small holdings, less than 5,000 acres apiece. Large holdings, comprising more than 50,000 acres, made up 41 percent of the total. The remainder, 13 percent, was in holdings of medium size. The acreages for the subregion and its districts are set down in table 8, where they are further subdivided by what

are termed "type-site classes." These classes, which are essentially forest productivity classes, are brought into the record at this point so that their ownership can be traced henceforth and they can be used as a basis for judging the potential timber yields of the future. The kind of forest included in each class is explained briefly at the foot of table 8 and fully in the introduction to Appendix A.

Large private holdings made up 49 percent of the privately owned commercial forest land in the Puget Sound district (table 9) and thus predominated over other size classes in that district. In the Columbia River district, however, large holdings occupied less total acreage than small, and in the Southwest Oregon district they constituted a mere three-tenths of the private acreage. Small- and medium-size holdings, on the other hand, increased in relative importance from the north to the south end of the subregion, both being most extensive in the Southwest Oregon district. In all three districts, the medium-size properties made up the least acreage.

Table 8. — Commercial forest-land acreage in the Douglas-fir subregion, by district, owner class, and forest type-site class; decade of 1950's

(In thousand acres)

ENTIRE SUBREGION

| Type-site class[1] | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| 1 | 2,779 | 618 | 2,062 | 1,328 | 867 | 1,051 | 8,705 |
| 2 | 1,708 | 529 | 1,938 | 1,849 | 954 | 649 | 7,627 |
| 3 | 578 | 379 | 1,174 | 2,480 | 611 | 388 | 5,610 |
| 4 | 93 | 48 | 40 | 1,687 | 69 | 114 | 2,051 |
| 5 | 290 | 169 | 907 | 149 | 71 | 187 | 1,773 |
| All | 5,448 | 1,743 | 6,121 | 7,493 | 2,572 | 2,389 | 25,766 |
| PUGET SOUND DISTRICT | | | | | | | |
| 1 | 949 | 93 | 471 | 173 | 9 | 318 | 2,013 |
| 2 | 576 | 77 | 580 | 416 | 45 | 245 | 1,939 |
| 3 | 353 | 130 | 447 | 617 | 55 | 293 | 1,895 |
| 4 | 36 | 12 | 12 | 521 | 15 | 100 | 696 |
| 5 | 228 | 51 | 406 | 18 | 28 | 107 | 838 |
| All | 2,142 | 363 | 1,916 | 1,745 | 152 | 1,063 | 7,381 |
| COLUMBIA RIVER DISTRICT | | | | | | | |
| 1 | 1,263 | 403 | 1,086 | 954 | 255 | 666 | 4,627 |
| 2 | 915 | 272 | 849 | 956 | 325 | 333 | 3,650 |
| 3 | 163 | 93 | 337 | 927 | 255 | 87 | 1,862 |
| 4 | 54 | 12 | 26 | 664 | 24 | 12 | 792 |
| 5 | 46 | 65 | 411 | 60 | 23 | 74 | 679 |
| All | 2,441 | 845 | 2,709 | 3,561 | 882 | 1,172 | 11,610 |
| SOUTHWEST OREGON DISTRICT | | | | | | | |
| 1 | 567 | 122 | 505 | 201 | 603 | 67 | 2,065 |
| 2 | 217 | 180 | 509 | 477 | 584 | 71 | 2,038 |
| 3 | 62 | 156 | 390 | 936 | 301 | 8 | 1,853 |
| 4 | 3 | 24 | 2 | 502 | 30 | 2 | 563 |
| 5 | 16 | 53 | 90 | 71 | 20 | 6 | 256 |
| All | 865 | 535 | 1,496 | 2,187 | 1,538 | 154 | 6,775 |

[1] Principal forests in each class: 1.—Douglas-fir on sites I and II (average index, 170). 2.—Douglas-fir on site III (140). 3.—Douglas-fir on sites IV and V (110). 4.—Upper-slope mixtures. 5.—Hardwood types on all sites. For full explanation, see Appendix A

Table 9. — Proportions of the private commercial forest land in each district of the Douglas-fir subregion that fall into each size class of holding, decade of 1950's (In percent)

| District | Large holding | Medium holding | Small holding | All private holdings |
|---|---|---|---|---|
| Puget Sound | 49 | 8 | 43 | 100 |
| Columbia River | 41 | 14 | 45 | 100 |
| Southwest Oregon | 30 | 18 | 52 | 100 |
| All districts | 41 | 13 | 46 | 100 |

The small private forest holdings are about equally divided between farm and nonfarm ownership in the subregion as a whole, and in the Puget Sound district, also, the acreages of the two groups are not greatly different (table 10). However, in the Columbia River district there is nearly twice as much farm woodland as nonfarm in small holdings, while in the Southwest Oregon district, the proportions are reversed. Some of the causes of this are discussed later, where the farm-nonfarm distinction is used in tracing probable future trends in the small forest holdings.

Another useful means for describing the small holdings is a subdivision by size class. The range of sizes below 5,000 acres covers, after all, a very wide variety of situations. For example, the 10-acre plot is quite a different kind of forest, with possibly a much different future, from the 4,000-acre tract. Acreages subdivided into four size classes are given in table 11. When the varying range of these classes is taken into account (a range of 90 acres in the smallest increasing to 3,000 acres in the largest), it becomes evident that the distribution of holdings is heavily skewed toward the smallest ones: the class from 10 to 99 acres is the most prominent—in acreage and, of course, in numbers. The increasing prominence of the smaller classes is most marked in the Puget Sound district, least so in the Southwest Oregon.

Table 10. — Commercial forest land in small private holdings in the Douglas-fir subregion, by farm and nonfarm ownership and district; decade of 1950's (In thousand acres)

| District | Farm holdings | Nonfarm holdings | All small holdings |
|---|---|---|---|
| Puget Sound | 824 | 1,092 | 1,916 |
| Columbia River | 1,734 | 975 | 2,709 |
| Southwest Oregon | 480 | 1,016 | 1,496 |
| All districts | 3,038 | 3,083 | 6,121 |

Table 11. — Commercial forest land in small private holdings in the Douglas-fir subregion, by size class and district; decade of 1950's
(In thousand acres)

| District | Size class | | | | |
|---|---|---|---|---|---|
| | 10-99 acres | 100-499 acres | 500-1,999 acres | 2,000-4,999 acres | All classes |
| Puget Sound | 766 | 825 | 287 | 38 | 1,916 |
| Columbia River | 731 | 1,219 | 569 | 190 | 2,709 |
| Southwest Oregon | 254 | 643 | 404 | 195 | 1,496 |
| All districts | 1,751 | 2,687 | 1,260 | 423 | 6,121 |

What changes in the present pattern of private commercial forest-land ownership may reasonably be expected during the next four decades? This question will be explored first with an eye to the large private holdings and then to the medium and small holdings.

Large holdings.—One of the most dramatic trends in the forest economy of the Douglas-fir subregion today is the growth of the large land holdings. In progress ever since the turn of the economic tide in the mid-1930's, this current growth of big holdings reached its highest rate in the years following World War II. Some of the growth has taken place as forest owners with tracts of medium size have, through acquisition of other medium-size and of small forest properties, expanded above the 50,000-acre mark. But the bulk of it has occurred through the enlargement of properties already in the big class. Most owners of such tracts, typically diversified wood-manufacturing corporations, have carried on vigorous land acquisition programs, buying up both contiguous and scattered holdings in the small and medium classes within what they considered to be their operating territories. Many private forest owners have been approached by one or more of these big buyers and know quite clearly to whom they could sell their land, and at what price, if they choose to do so.

Besides the flow of private forest lands from the small and middle categories into the large holdings, there have been some mergers between big holders that have heightened the concentration of ownership. Thus, while the large properties have exhibited great increases in acreage, they have shown no significant increase in numbers. In the mid-1950's, there were fewer than 30 of them in the Douglas-fir subregion: about four-hundredths of one percent of the private forest owners, holding four-tenths of the private commercial forest land.

The growing concentration of private forest ownership in the Douglas-fir subregion may be regarded as one aspect of the whole trend toward bigness in American economic life. Just as this trend is widely expected to continue in force, so the growth of forest concentration may be regarded as a continuing feature of Douglas-fir country, though the rate of growth will very possibly not be so high in future as it was in the first decade after World War II.

Concentration of forest ownership is the evidence and the result of the inherent strength of big owners, notably those whose ownership is integrated with the operation of diversified wood-manufacturing plants. With their low guiding rates of interest, fortified by their long view of the future as corporations, these big owners tend to set a higher value upon forest land than do other owners, a value which is reflected in their successful bidding in the land market. This advantage is strengthened by their diversification and by their ability to employ specialized technicians, both of which permit them to realize the full value of the land's timber products. To the extent that they enjoy economies of scale in manufacturing and product distribution, these economies prompt them to secure the essential raw material sources by means of enlarged forest ownership. Their increasing bigness helps them increasingly to spread their risks, to gain certain income tax advantages, and to afford the use of extensive landownership as a hedge against general monetary inflation.

However, as the concentration of private forest ownership continues, it meets—and will meet—increasing resistances. The most obvious and forceful of these resistances is the continuously greater strength of the other forest owners who remain, whose properties must be bought if concentration is to progress further. Forestland prices rise, while the average quality and desirability of purchasable tracts decline. Competition for forest land becomes a noticeable element in the market. The big owner who has been buying up farms in fringe areas finds himself increasingly at odds with the farm interests who fear the loss of a base sufficient to maintain essential community and agricultural services. The corporation that has bought more than a certain critical fraction of the land in a county may thereby acquire hard problems in public relations and in property taxation. And always, as a firm's size grows, the dangers increase of its running against Federal antitrust policy.

What is foreseen, then, is a continuing but slackening increase in the acreage of commercial forest in large private holdings. The future trends assumed vary somewhat from district to district within the Douglas-fir subregion.

The Puget Sound district has an older forest economy than either of the other two. Forest industry became generally established earlier and is now more diversified. Processing is carried to higher levels of refinement. Apparently, under the press of dwindling raw material supplies, industry was early forced into the protective measure of acquiring large blocks of timberland. Large-scale owners now hold half of the private commercial forest. The possibility of further concentration is limited. Holdings of medium size, which ordinarily are prime land for acquisition, have been reduced to well under a tenth of the private forest acreage and now constitute to some extent an unapproachable hard core. Remaining farm woodlands, too, are believed to be a relatively permanent class. Any further increase in the large holdings must come principally from the small nonfarm tracts, which make up about a fourth of the private commercial forest land, though here the great proportion of very small tracts (table 11) presents a barrier to their acquisition.

In the Columbia River and Southwest Oregon districts, and particularly in the latter, wood-industry development is less advanced. As management of the forest resource becomes more intensive in western Oregon, these two districts are expected to experience somewhat the same shifts in forest ownership as will have already occurred in the Puget Sound district: increases in large holdings, heavy reductions in small nonfarm tracts, moderate reductions in the medium class, and light reductions in form woodland.

The net result of these expectations is tabulated at the end of this chapter, following some further analysis of the situation on the medium and small forest properties.

Medium and small-nonfarm holdings.—To turn from the big holdings to the small nonfarm tracts is to shift at once from examples of the strongest private forest ownership in the Douglas-fir subregion to examples of the weakest. The small nonfarm and the medium-size properties are here grouped, not because their stories are just the same but because they have some characteristics that differ in degree rather than in kind. For example, so far as outlook for the future is concerned, the medium holdings that are owned in integration with a sawmill (the typical case) grade imperceptibly into the holdings of less than 5,000 acres that are similarly owned. And the small, unintegrated, individually owned tract has its close counterpart in the size range above 5,000 acres.

Consequently, where this discussion treats one particular size group or the other, it must be interpreted as applying to some extent also on the opposite side of the 5,000-acre boundary.

The situation of many middle-scale forest owners is reflected in the remarks of one lumberman, the third-generation manager of his family's woods and mill business. "We are too big to get real savings of overhead," he says, "and too small to diversify; and we can't expand because we must hold our earnings in liquid form to be able to pay inheritance taxes."

This firm owns 20-odd thousand acres of timberland, not enough for permanent operation of its mill. Right after the War, it bought several small tracts to enlarge its holdings, but now land prices have been pushed up beyond what it can reasonably afford. Entering the market for Government timber, it finds itself consistently outbid both by little independent loggers and big companies. The manager believes that if he could add a veneer lathe, stud mill, and chipper he might be able to pay $12.50 more per thousand feet for stumpage. What he would like most is a pulpmill, but this appears to be out of reach, even as a cooperative venture with the other medium-size concerns in the area.

He has standing offers for his forest land from his two largest competitors. The price is high by comparison with the earnings that he himself is able to make from the land. His sense of family obligation has kept him going. Nevertheless, he believes that to sell out is inevitable, if not in this generation then surely in the next, for his sons have shown no great enthusiasm or aptitude for the lumber business.

Small nonfarm forest properties give some evidence of being even more weakly held than properties of middle size. They are almost always owned by individuals, and consequently tenure and the policies applied to these properties have little continuity. They are apt to come on the market at least once each generation, and many of them change hands much oftener. The tendency of the market is to transfer these tracts little by little into stronger ownership, which may well mean incorporating them into big holdings.

Most of the small nonfarm forests are too small for any effective integration with other enterprises such as manufacturing. This fact, taken with the uncertainties that face the small-scale timber seller and the technical handicaps under which he operates both in growing and in marketing timber, creates a strong financial disadvantage for the owner. The size of his tract presents also serious problems in organization and administration for timber output—as, for example, the irregularity, small quantity, and intermittent nature of the harvest.

Many owners of small forest properties, it is true, are primarily interested in values other than timber—for instance, recreation or the mere pleasure of land ownership. But such owners, too, have problems, which they share with those who are timber oriented—problems of protecting and managing the property from a distance and of financial insecurity.

Thus, taking nonfarm forest holdings as a broad class, one is impressed by the number and strength of the forces working toward consolidation of these holdings into larger and larger units.

Future trends of consolidation may be expected to differ among the three districts of the Douglas-fir subregion. In the Puget Sound district, for reasons touched upon earlier, the outlook is for comparatively small further changes. Along with the fact that the forest economy of the district is the most advanced, there is the circumstance that markets for wood, including pulpwood, are in general more highly developed and therefore more favorable to timber management on smaller tracts. In the Columbia River district, there is more opportunity and prospect for ownership changes toward consolidation; and in the Southwest Oregon district there is the most of all.

Small farm holdings.—The farm forest holdings, in contrast to the small forest properties that are not a part of farms, must be regarded as among the more stable and permanent features of the landownership pattern. Their permanency is in part fortuitous: Physically attached to farms, many of them cannot very well change class of ownership unless the farm is abandoned, no matter how little regard the owner may have for their management. But the relative permanency of the farm forests arises also out of certain inherent advantages in administration: notably the opportunity for integration with other farm enterprises and for joint use of labor and equipment.

Farm forests share the advantage of farmlands generally in the Douglas-fir subregion that they change hands less frequently than nonfarm rural properties.

In a survey of small woodlands, both farm and nonfarm, it was found that 63 percent of the farm tracts, as against 43 percent of the nonfarm, have been owned by the same person for 20 years or longer. In a sample about equally divided between farm and nonfarm owners, only 15 percent of those who expressed the intention of selling their land were farmers.

Furthermore, the farmers of the Douglas-fir country, unlike those in some other regions, appear very generally to take a strong interest in their timber resources. They observe at first hand that timber is one of the principal bases of rural economic life. They often have outside experience as woods workers. And they frequently find that their forest land, when devoted to timber growing, is one of the more productive parts of their farm. Although timber income is but a small part of aggregate farm income in the subregion, it is an important part on many farms. As a result, farmers tend to be reluctant to give up their forest land, even when it is so situated that it could be acquired advantageously by larger timberland owners.

There is expected to be only a slow drift of commercial forest acreage out of farm ownership into nonfarm, principally into the large holdings. Again the drift bids fair to be most pronounced in the Southwest Oregon district, least in the Puget Sound.

The net result of all anticipated shifts in ownership of commercial forest land during the coming four decades is set down in table 12. This table may be compared with table 8, which describes the current situation. Table 12 accounts for prospective changes in land use, under the principal assumptions described earlier, as well as for the changes in ownership.

Table 12. — Commercial forest land acreage in the Douglas-fir subregion, district, owner class, and forest type-site class—principal assumption for the year 2000
(In thousand acres)

| Type-site class | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| **ENTIRE SUBREGION** | | | | | | | |
| 1 | 4,712 | 156 | 390 | 1,223 | 836 | 991 | 8,308 |
| 2 | 2,991 | 230 | 813 | 1,769 | 922 | 601 | 7,326 |
| 3 | 796 | 220 | 1,031 | 2,434 | 584 | 355 | 5,420 |
| 4 | 86 | 46 | 39 | 1,770 | 66 | 96 | 2,103 |
| 5 | 274 | 159 | 874 | 125 | 68 | 170 | 1,670 |
| All | 8,859 | 811 | 3,147 | 7,321 | 2,476 | 2,213 | 24,827 |
| **PUGET SOUND DISTRICT** | | | | | | | |
| 1 | 1,283 | 98 | 75 | 154 | 9 | 302 | 1,921 |
| 2 | 932 | 76 | 181 | 406 | 44 | 229 | 1,868 |
| 3 | 331 | 127 | 432 | 615 | 52 | 278 | 1,835 |
| 4 | 34 | 12 | 13 | 585 | 15 | 94 | 753 |
| 5 | 217 | 48 | 392 | 15 | 27 | 100 | 799 |
| All | 2,797 | 361 | 1,093 | 1,775 | 147 | 1,003 | 7,176 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | |
| 1 | 2,378 | 38 | 230 | 896 | 245 | 632 | 4,419 |
| 2 | 1,270 | 148 | 548 | 907 | 313 | 310 | 3,496 |
| 3 | 155 | 89 | 326 | 896 | 244 | 77 | 1,787 |
| 4 | 50 | 12 | 24 | 666 | 22 | 2 | 776 |
| 5 | 42 | 61 | 396 | 43 | 22 | 64 | 628 |
| All | 3,895 | 348 | 1,524 | 3,408 | 846 | 1,085 | 11,106 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | |
| 1 | 1,051 | 20 | 85 | 173 | 582 | 57 | 1,968 |
| 2 | 789 | 6 | 84 | 456 | 565 | 62 | 1,962 |
| 3 | 310 | 4 | 273 | 923 | 288 | -- | 1,798 |
| 4 | 2 | 22 | 2 | 519 | 29 | -- | 574 |
| 5 | 15 | 50 | 86 | 67 | 19 | 6 | 243 |
| All | 2,167 | 102 | 530 | 2,138 | 1,483 | 125 | 6,545 |

# Chapter 3

## Timber Yields in the Long Run

The purpose of this chapter is to work out some estimates of the annual yields of timber that might economically be produced in the Douglas-fir subregion in the long run. The purpose is to figure annual yields under different assumptions and thereby to test the effect of alternative developments upon the yield. In the course of these conjectures, the question of what timber rotations and management measures are economical will also be touched upon, by way of following up the principles explored in chapter 2. Thus, in a sense this chapter is a study of the long-run timber supply, and its object is to consider the contribution to the national timber supply that the Douglas-fir subregion might appropriately make in the long run.

To analyze longrun timber yields, the following steps will be taken: First, the economical yield per acre will be worked out, under one set of assumptions regarding revenues and costs, for the conservative forest owner with a saw log objective. Second, economical per acre yields will be estimated, under single sets of assumptions, for other classes of owners with a saw log objective and for each class with a wood objective. Third, the foregoing per acre yields will be translated into total annual yields for the Douglas-fir subregion under a single set of assumptions regarding land use and forest ownership. Fourth, the total timber supply of the subregion will be analyzed in relation to alternative sets of assumptions. Fifth, the implications of the findings will be studied.

### Economical Yield Under Conservative Management

Take the case of the conservative owner of a tract of type-site 2 forest (Douglas-fir, site III). Suppose that such an owner plans a management program for continuous saw log production. An even-aged silvicultural system is to be followed, with light intermediate cuttings beginning early enough in the life of each stand, and continuing frequently enough, to permit high utilization of the site. After the final harvest cut, prompt regeneration of a good quality stand is to be assured by whatever means are necessary. The forest is to be managed under close professional supervision. It is to be provided with a road network, or equivalent means of access, to the high standard described in chapter 2. All trees 6 inches and larger, d.b.h., are to be utilized to a 4-inch top; and losses from fire and other agencies will be held to a negligible level. Neither fertilization nor pruning will be practiced. Value growth arising from conversion and regeneration cost differentials will amount to 1 percent annually, but there will be no other trend in unit value to affect this growth: the prospective value will be $40 (1957-59 basis) per thousand board feet, Scribner rule, in the terms of figure 5. How much timber can this owner be expected to produce on the average acre in the long run?

Growth of managed young timber.—The first question to answer concerns the timber growth that can be expected under the prescribed management program. Since growth will vary with stand age and also with the amount of growing stock carried between intermediate cuts, growth must be estimated in relation to both these variables.

Incidentally, to assume that growth at any age is related to growing stock is neither to affirm nor to deny the so-called plateau effect: that above a certain minimum stocking (often said to be about half of the maximum that the site is capable of carrying at the stand age in question), the well-spaced stand utilizes the site fully, so that total annual growth of organic matter is fixed. This study is concerned with the growth, not of all organic matter, but of merchantable timber. Furthermore, if even an approximate plateau exists, then the location of the edge of the plateau becomes a matter of great concern, since, as will soon become evident, it will probably fix the economical level of stocking for a wide range of owners. That is to say, the question of the growth-stocking relationship is as generally pertinent as that of the growth-age relationship.

No one knows for sure the relation of Douglas-fir growth to stand age and stocking under intensive management. The best that one can do is to gather the available evidence from the Douglas-fir subregion and from European records and interpret it as he can. Such an interpretation was made by Briegleb (2) in 1952. Additional data are to be found in the more recent published work of Grah (3) and Smith (9). This study begins with Briegleb's findings, tempers them with the published and unpublished data that have become available since 1952, and converts the result into the units of measure required here. For forest type-site 2, the board-foot growth derived by this approach is given in figure 8. The basic estimates in both board feet and cubic feet for all type sites are detailed in tables 33-40, Appendix B.

To study the meaning of figure 8, take the 60-year curve as a case in point. This curve shows a current annual growth of about 700 board feet (Scribner rule) per acre in a stand of 10,000 board feet per acre. Such a stand is a little more than 40 percent stocked in terms of the normal yield table. The curve reading represents an estimate that if an acre of Douglas-fir on site III is thinned from an early age in such a manner that at age 60 it supports 10,000 board feet as well distributed as possible, stemwise, for utilization of the site, the current (gross) growth will be about 700 board feet per year. Likewise, by reading the same curve at 20,000 feet, one obtains the estimate that if a stand is brought up through a thinning regime (clearly, a different regime from the one foregoing) to a volume of 20,000 feet per acre at 60 years, so distributed that the site will be used as fully as possible, then the stand's current annual growth will be about 1,330 board feet per acre. Thus the positions along the 60-year curve do not represent immediate alternatives for the forest owner—he cannot take a 60-year-old growing stock of 20,000 feet per acre growing at the rate of 1,330 feet annually, cut out half the volume, and expect the residual to grow at a 700-foot rate. However,

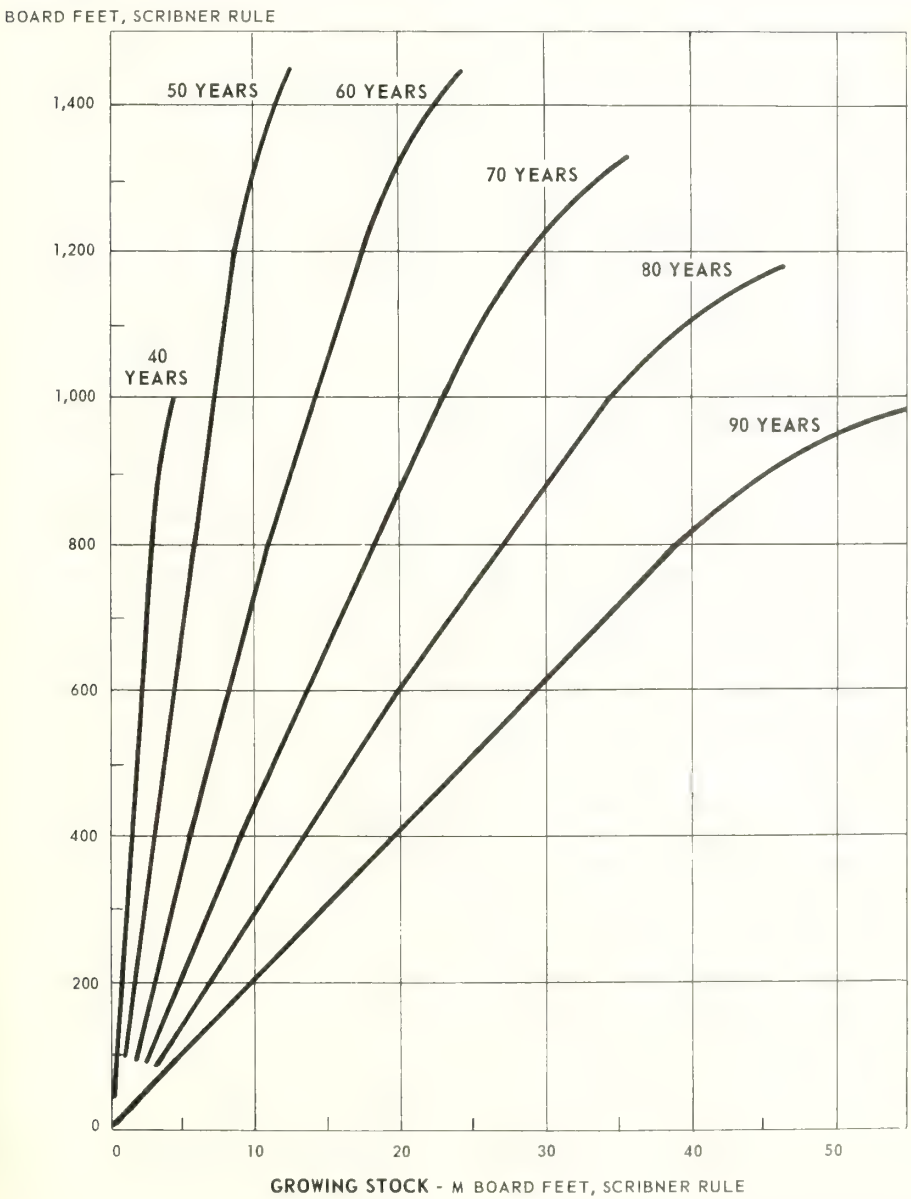


Figure 8.—Estimated current annual gross growth per acre in relation to stand age and growing stock, site III Douglas-fir managed under a thinning regime.

the positions along this curve and all the others in figure 8 are intended to represent longrun alternatives, any one of which may be attained by the forest owner if he plans ahead from the start of the rotation and carries out his thinning regime accordingly.

Rates of return from intensive management.—From an inspection of figure 8 it becomes obvious that the longrun alternatives there represented are not equally fruitful. Take again the 60-year curve as an example. Readings at 1,000-foot intervals of stocking from 14,000 to 24,000 are detailed in table 13, columns 1 and 3. By planning for a 15,000- rather than a 14,000-board foot stocking, the forest owner can get 68 board feet more annual growth (col. 4). This extra growth, expressed in proportion to the extra growing stock (col. 2) required to produce it, constitutes a return of 6.8 percent (col. 5). But at higher levels of stocking, the reward from increasing the growing stock is continually less, falling to 2 percent in the interval between 23,000 and 24,000 board feet of growing stock.

One may well suppose that the forest owner whose guiding rate of interest is 3 percent will not wish to carry more than about 21,000 board feet of growing stock per acre in 60-year stands of Douglas-fir on site III under a thinning regime. If his guiding rate were 6 percent, about 17,000 feet would be his limit. And if his guiding rate were above 7 percent, he would not want to grow his timber to 60 years of age at all, but would confine himself to a shorter rotation during which it would be possible, by thinning, to keep the stand growing at a rate satisfactory to him.

Table 13. — Rate of return on extra growing stock as related to stocking in a thinned 60-year-old, 1-acre stand of Douglas-fir on site III

| Growing stock | | Current annual growth | | Return on extra growing stock |
|---|---|---|---|---|
| Total | Extra | Total | Extra | |
| (1) | (2) | (3) | (4) | (5) |
| Board feet | | | | Percent |
| 14,000 | -- | 972 | -- | -- |
| 15,000 | 1,000 | 1,040 | 68 | 6.8 |
| 16,000 | 1,000 | 1,107 | 67 | 6.7 |
| 17,000 | 1,000 | 1,173 | 66 | 6.6 |
| 18,000 | 1,000 | 1,232 | 59 | 5.9 |
| 19,000 | 1,000 | 1,284 | 52 | 5.2 |
| 20,000 | 1,000 | 1,328 | 44 | 4.4 |
| 21,000 | 1,000 | 1,365 | 37 | 3.7 |
| 22,000 | 1,000 | 1,395 | 30 | 3.0 |
| 23,000 | 1,000 | 1,420 | 25 | 2.5 |
| 24,000 | 1,000 | 1,440 | 20 | 2.0 |

Likewise, by locating the 3-percent points on the successive curves in figure 8, one can trace out a thinning regime for conservative forest owners. The result is the series analyzed in table 14, which is set up after the general pattern and reasoning of table 3.

Economical rotation and output.—Table 14 analyzes a series of stands from 30 to 90 years of age, at 10-year intervals (col. 1). Columns 2 and 6 are read from the growth curves illustrated in figure 8 at normal stocking for young stands where the growth rate is very high, at the 3-percent point for older stands up through 80 years, and at the approximate edge of the plateau for the 90-year stand, which is added, even though its growth rate fails to reach 3 percent, in order to extend the data a bit further for the later purpose of curve drawing. The indicated thinning regime maintains approximately normal stocking to age 50 and gradually reduces normality thereafter to around 75 percent at the end of the rotation.

Columns 3, 4, and 5 in table 14 are the counterpart of columns 6, 7, and 8 in table 3. However, the board-foot unit of measure is retained in table 14.

Column 7 shows the amount of the decadal growth per acre that is not needed as growing stock and can be taken in thinning. Thus the first entry in the column, 1,090 board feet, is derived by subtracting the difference between 4,500 and 300 (col. 1) from 5,290 (col. 6).

Table 14. — Rate of return on extra growing stock as related to average annual timber yield per acre of seven hypothetical regulated Douglas-fir forests on site III managed under a thinning regime at a guiding interest rate of 3 percent

| Rotation | Growing stock | | | | Growth per decade | | Yield | | | Return on extra growing stock |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cumulative | | Per acre | | | | Cumulative | Annual per acre | | |
| (years) | Oldest acre | All acres | Total | Extra | Gross | Cut | | Total | Extra | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| | Bd. ft. | M bd. ft. | Board feet | | | | | | | Percent |
| 30 | 300 | 1.5 | 50 | -- | -- | -- | 300 | 10 | -- | -- |
| 40 | 4,500 | 25.5 | 638 | 588 | 5,290 | 1,090 | 5,590 | 140 | 130 | 22.1 |
| 50 | 12,400 | 110.0 | 2,200 | 1,562 | 9,950 | 2,050 | 15,540 | 311 | 171 | 10.9 |
| 60 | 21,100 | 277.5 | 4,625 | 2,425 | 14,360 | 5,660 | 29,900 | 498 | 187 | 7.7 |
| 70 | 28,400 | 525.0 | 7,500 | 2,875 | 13,710 | 6,410 | 43,610 | 623 | 125 | 4.3 |
| 80 | 33,400 | 834.0 | 10,425 | 2,925 | 11,920 | 6,920 | 55,530 | 694 | 71 | 2.4 |
| 90 | 36,800 | 1,185.0 | 13,167 | 2,742 | 9,050 | 5,650 | 64,580 | 718 | 24 | .9 |

Column 8, the counterpart of column 2 in table 3, records the yield that would be available from a final harvest cut at the stand age in question plus all intermediate cuts at younger ages. This yield is expressed per acre of the entire forest in column 9, the counterpart of columns 3 and 4 in table 3.

Columns 10 and 11 match columns 5 and 9, respectively, in table 3. When the 1-percent allowance for conversion and regeneration costs is added to the return percentages in column 11 and the result is curved with age and with yield, a rotation of close to 80 years is indicated with an average annual yield from intermediate and harvest cuts of about 680 board feet per acre. Somewhat more than 40 percent of the total yield is from the thinnings, and less than 60 percent is from the final harvest. Growth rate of individual trees is maintained at no fewer than about 6 rings per inch. The breast-high diameter of crop trees at the end of the rotation is in the neighborhood of 22 to 24 inches.

In addition to the yield of saw logs in board feet, the regime of management will produce a volume of smaller diameter wood from young trees removed in thinnings and from the tops of sawtimber trees. Analysis of stand tables provides the estimate that the yield of such material will average 20 cubic feet per acre per year.

The foregoing yields of 680 board feet and 20 additional cubic feet may be regarded as gross, in the sense that they are estimated from plot data. Experience usually shows that the per acre yields obtainable on plots can never quite be reached on whole forest properties. A reduction allowance is needed for blank spots, errors in silvicultural judgment, and unaccounted losses. Furthermore, in the present analysis it is desired to allow for losses in yield arising from the inevitable presence of hardwoods, even in forests managed for conifers, and for the element of uncertainty. Accordingly, the estimated gross yields are cut back 15 percent to net amounts of 578 board feet and 17 additional cubic feet per acre per year. These net yields are judged to represent the reasonable potentialities of timber management on conservatively held site III forest properties in the long run, under the assumptions here being followed.

## Yields Under All Classes of Ownership

The same analysis that has just been outlined was made for each of the three classes of forest owners, each of the two product objectives, and each of the four conifer type-site classes. The result is given in table 15. For conservative and intermediate owners, net yields are derived from the gross by applying a reduction factor of 15 percent. However, for the exploitive owner, in order to make some allowance for greater uncertainties, especially those associated with regeneration, a 20-percent cutback is taken.

Table 15. — Estimated forest rotation and annual per acre yield under a thinning regime, by owner class, product objective, and forest type-site class

| Forest type-site class | Saw log objective | | | | | Wood objective | | |
|---|---|---|---|---|---|---|---|---|
| | Rotation | Yield per acre | | | | | | |
| | | Gross | | Net | | | | |
| | | Saw logs | Other wood | Saw logs | Other wood | Rotation | Yield per acre | |
| | | | | | | | Gross | Net |
| | Years | Bd. ft. | Cu. ft. | Bd. ft. | Cu. ft. | Years | — — — Cu. ft. — — — | |
| **CONSERVATIVE OWNER** | | | | | | | | |
| 1 | 70 | 980 | 25 | 833 | 21 | 45 | 225 | 191 |
| 2 | 80 | 680 | 20 | 578 | 17 | 50 | 180 | 153 |
| 3 | 90 | 350 | 15 | 298 | 13 | 60 | 120 | 102 |
| 4 | 95 | 250 | 15 | 212 | 13 | 60 | 100 | 85 |
| **INTERMEDIATE OWNER** | | | | | | | | |
| 1 | 55 | 790 | 25 | 672 | 21 | 40 | 190 | 162 |
| 2 | 60 | 470 | 20 | 400 | 17 | 45 | 155 | 132 |
| 3 | 75 | 250 | 15 | 212 | 13 | 50 | 100 | 85 |
| 4 | 80 | 190 | 15 | 162 | 13 | 50 | 80 | 68 |
| **EXPLOITIVE OWNER** | | | | | | | | |
| 1 | 45 | 530 | 20 | 424 | 16 | 30 | 150 | 120 |
| 2 | 50 | 280 | 15 | 224 | 12 | 35 | 115 | 92 |
| 3 | 55 | 130 | 10 | 104 | 8 | 35 | 65 | 52 |
| 4 | 60 | 90 | 10 | 72 | 8 | 35 | 55 | 44 |

Rotations and per acre yields.—In table 15, one finds rotations ranging from 30 to 95 years. The longer rotations are those for the more conservative owners and the poorer sites. Also, under a saw log objective the rotation is markedly longer than under a wood objective. As compared with rotations indicated for a one-cut program of management, all these rotations are lengthened by the assumption that intermediate cutting will be done. For example, the 80-, 60-, and 50-year saw log rotations for the three classes of owners of type-site 2 are to be compared with rotations of about 70, 55, and 40 years, respectively, indicated for the same owners in table 3, where a one-cut program is assumed. (Here rotations are estimated in the table after adding the 1-percent conversion- and regeneration-cost allowance to the figures in column 9.)

It is important to make clear the spirit in which rotation ages are set forth here and elsewhere in this report and the use visualized for rotation age in forest management. A rotation age is not seen as a fixed or an absolute determinant of harvest time. It is not even seen in practice as the principal guide to the time of harvest. A manager's decision to cut a stand is conceived as resting on con-

siderations of timber value-growth rate, nontimber forest values, alternative opportunities for the use of capital, the changing timber requirements of the plant or market, and the like. Thus, in practice rotation age is believed to be a flexible tool of management. In this report it is used as an analytical device—an index of timber management intensity. The forest rotation is intended to indicate the consequences of management more than the form of it, just as the perfectly regulated forest serves as a basis for reasoning rather than a representation of the form of the real forest.

The yields of table 15 show a very wide range. Gross yields extend from about 100 to nearly 1000 board feet and from 2/3 to more than 2-1/2 cords per acre per year. The higher the site and the lower the guiding interest rate, the greater the yield. Calculations for type-site 4, mostly the upper slopes, are based on the assumption that these forests will grow approximately like Douglas-fir on site 100. The resulting rotations may not be far off, but the yields undoubtedly are conservative, especially in view of the assumption that noble or red fir will be favored on these lands. This element of conservatism has been retained in the estimates to provide an allowance for the many uncertainties regarding the management of the upper slopes.

Forest acreage.—The next step in this analysis of longrun timber yields is to estimate the forest acreages to which the per acre yields of table 15 apply. For this purpose, table 12 provides a starting point. Beginning with that table, it is necessary to estimate the conifer sites of the lands shown in previous tables as bearing a hardwood cover (type-site 5) and to allocate the hardwood acreages to the other four type-sites. Such allocation is required because of lack of satisfactory hardwood yield data. In this manner, hardwood growth is allowed for in the calculation of longrun yield. A basis for the allocation is the site records of the Forest Survey and the forest site maps of the subregion. These, supplemented by some general judgment, produce the result shown in table 16.

Table 16. — Estimated commercial forest land acreage in the Douglas-fir subregion in the long run, by district, owner class, and conifer type-site class

(In thousand acres)

| Conifer type-site class | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| **ENTIRE SUBREGION** | | | | | | | |
| 1 | 4,778 | 221 | 787 | 1,229 | 851 | 1,042 | 8,908 |
| 2 | 3,177 | 319 | 1,281 | 1,823 | 962 | 699 | 8,261 |
| 3 | 818 | 225 | 1,040 | 2,499 | 597 | 376 | 5,555 |
| 4 | 86 | 46 | 39 | 1,770 | 66 | 96 | 2,103 |
| All | 8,859 | 811 | 3,147 | 7,321 | 2,476 | 2,213 | 24,827 |
| **PUGET SOUND DISTRICT** | | | | | | | |
| 1 | 1,316 | 105 | 173 | 156 | 16 | 317 | 2,083 |
| 2 | 1,095 | 117 | 475 | 412 | 58 | 304 | 2,461 |
| 3 | 352 | 127 | 432 | 622 | 58 | 288 | 1,879 |
| 4 | 34 | 12 | 13 | 585 | 15 | 94 | 753 |
| All | 2,797 | 361 | 1,093 | 1,775 | 147 | 1,003 | 7,176 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | |
| 1 | 2,409 | 84 | 507 | 900 | 251 | 667 | 4,818 |
| 2 | 1,281 | 163 | 667 | 935 | 327 | 329 | 3,702 |
| 3 | 155 | 89 | 326 | 907 | 246 | 87 | 1,810 |
| 4 | 50 | 12 | 24 | 666 | 22 | 2 | 776 |
| All | 3,895 | 348 | 1,524 | 3,408 | 846 | 1,085 | 11,106 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | |
| 1 | 1,053 | 32 | 107 | 173 | 584 | 58 | 2,007 |
| 2 | 801 | 39 | 139 | 476 | 577 | 66 | 2,098 |
| 3 | 311 | 9 | 282 | 970 | 293 | 1 | 1,866 |
| 4 | 2 | 22 | 2 | 519 | 29 | -- | 574 |
| All | 2,167 | 102 | 530 | 2,138 | 1,483 | 125 | 6,54[illegible] |

It is evident from table 16 that a great share of the productive potential of the Douglas-fir subregion lies in the Columbia River district. Not only is this district the largest of the three, but it contains proportionally more higher site lands and less of the lower sites than the other districts.

For the acreage data of table 16 to be usable, its forest-ownership classification must be translated into the classification of table 15; conservative, intermediate, and exploitive owners. It is assumed that in the long run, the translation may be made on the basis of the following percentages:

| | Conservative | Intermediate | Exploitive |
|---|---|---|---|
| Large private | 85 | 15 | 0 |
| Medium private | 20 | 70 | 10 |
| Small Private | | | |
| Farm | 10 | 20 | 70 |
| Nonfarm | 20 | 50 | 30 |
| Average | 10 | 30 | 60 |
| National Forest | 100 | 0 | 0 |
| Other Federal | 85 | 15 | 0 |
| Other public | 60 | 40 | 0 |

The result of the translation, for the Douglas-fir subregion as a whole, is given in table 17. The table allocates 75 percent of the entire commercial forest acreage to conservative ownership, 17 percent to intermediate, and 8 percent to exploitive ownership.

Table 17. — Estimated commercial forest land acreage in the Douglas-fir subregion in the long run, by owner class and conifer type-site class

| Conifer type-site class | Conservative owners | Intermediate owners | Exploitive owners | All owners |
|---|---|---|---|---|
| | Thousand acres | | | |
| 1 | 6,761 | 1,653 | 494 | 8,908 |
| 2 | 5,952 | 1,508 | 801 | 8,261 |
| 3 | 4,076 | 833 | 646 | 5,555 |
| 4 | 1,971 | 104 | 28 | 2,103 |
| All | 18,760 | 4,098 | 1,969 | 24,827 |

Total yields.—Total potential timber output of the Douglas-fir subregion in the long run may now be estimated by multiplying the acreages of table 17 by the yields of table 15. The estimates are shown in table 18. They add to 13.1 billion board feet and 0.4 billion additional cubic feet per year under a saw log objective, or 3.5 billion cubic feet per year under a wood objective. The average per acre yields represented by these amounts are 526 board feet and 17 additional cubic feet, and 141 cubic feet (about 1-2/3 cords). The total saw log yield of 13.1 billion board feet is about 7 percent above the subregion's average annual timber ontput during the decade of the 1950's. More than half of the total potential saw log yield is attributed to type-site I. More than four-fifths is attributed to conservative owners.

The potential longrun yield of 13.1 billion board feet is shown again in table 19, where it is allocated to the six classes of forest ownership used throughout most of this report. A little more than half of the potential is on private holdings, mostly the big holdings. About a fourth of it is on the National Forests. Currently, a little more than a fourth of the cut is from National Forests.

Some further interpretation of the longrun potential yield estimates of tables 18 and 19 will be offered toward the close of chapter 3.

Table 18. — Estimated total potential timber output per year from the Douglas-fir subregion in the long run, by product objective, owner class, and conifer type-site class

| Conifer type-site class | Conservative owners | Intermediate owners | Exploitive owners | All owners |
|---|---|---|---|---|
| | | Million board feet | | |
| **SAW LOG OBJECTIVE: SAW LOG YIELD** | | | | |
| 1 | 5,632 | 1,111 | 209 | 6,952 |
| 2 | 3,440 | 603 | 179 | 4,222 |
| 3 | 1,215 | 177 | 67 | 1,459 |
| 4 | 418 | 17 | 2 | 437 |
| All | 10,705 | 1,908 | 457 | 13,070 |
| | | Million cubic feet | | |
| **SAW LOG OBJECTIVE: YIELD OF OTHER WOOD** | | | | |
| 1 | 142.0 | 34.7 | 7.9 | 184.6 |
| 2 | 101.2 | 25.6 | 9.6 | 136.4 |
| 3 | 53.0 | 10.8 | 5.2 | 69.0 |
| 4 | 25.6 | 1.4 | .2 | 27.2 |
| All | 321.8 | 72.5 | 22.9 | 417.2 |
| | | Million cubic feet | | |
| **WOOD OBJECTIVE: TOTAL YIELD** | | | | |
| 1 | 1,291.4 | 267.8 | 59.3 | 1,618.5 |
| 2 | 910.7 | 199.1 | 73.7 | 1,183.5 |
| 3 | 415.8 | 70.8 | 33.6 | 520.2 |
| 4 | 167.5 | 7.1 | 1.2 | 175.8 |
| All | 2,785.4 | 544.8 | 167.8 | 3,498.0 |

Table 19. — Estimated total potential sawtimber output per year from the Douglas-fir subregion in the long run, by owner class and conifer type-site class

| Conifer type-site class | Private holdings | | | Public holdings | | | All holdings | Per acre average |
|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | | |
| | Million board feet | | | | | | | Board feet |
| 1 | 3,864 | 150 | 425 | 1,024 | 688 | 801 | 6,952 | 780 |
| 2 | 1,751 | 133 | 399 | 1,054 | 531 | 354 | 4,222 | 511 |
| 3 | 233 | 50 | 162 | 745 | 170 | 99 | 1,459 | 263 |
| 4 | 18 | 7 | 5 | 375 | 14 | 18 | 437 | 208 |
| All | 5,866 | 340 | 991 | 3,198 | 1,403 | 1,272 | 13,070 | 526 |

## Yields Under Alternative Assumptions

It is now possible to test the effect of alternative assumptions upon the long-run potential output. Tests will be made of the effect of (1) stumpage price, (2) interest rate, and (3) land management and use. The output data expressed in board feet (Scribner rule) and applying to a saw log objective will be used in these tests. The board foot data are chosen because they are more familiar and more readily interpretable. Major findings of the analysis will be generally applicable also to cubic foot yields.

Stumpage price.—From the review of the influences upon timber output in chapter 2, it appears that the prospective stumpage-price level (in relation to costs) may be expected to have an effect upon longrun timber yields through its influence upon certain types of management decisions, notably those in reference to land use, forest regeneration, and the use of fertilizer.

Estimates of the longrun response of timber output to price-level prospects ranging upward from $40 (1957-59 basis) per thousand board feet may be derived from the relationships developed in chapter 2, together with acreage and yield data from the present chapter. Thus, for example, with a price prospect of $100, the following extra annual yields may be possible in the long run beyond the 13.1 billion board feet judged to be obtainable with a $40 prospect: (1) from 750,000 acres of land formerly in farms, assuming an average yield of 400 board feet per acre per year, 0.3 billion feet; (2) from extra regeneration efforts of exploitive forest owners (fig. 6) on 1,969,000 acres, an average of 14.7 board feet per acre or about 29 million feet annually altogether; (3) from fertilizer programs of conservative owners on all sites (table 6), an average of 91.5 board feet per acre on 18,518,000 acres or 1,694 million board feet per year in total. These extra annual yields add to about 2.0 billion feet and make a total annual yield of 15.1 billion feet with the $100 price prospect.

With longrun prospective prices below $40, lower yields could be looked for, mainly because intermediate cutting would be discouraged. But the yields would still be substantial. Take a hypothetical case: even if anticipated price approached zero, such lands as remained in forest use would, under the protection program assumed, be free to grow timber. And the timber could be harvested from time to time. It is estimated that the region could produce all of 5 billion feet per year under these circumstances.

The foregoing estimates are expressed, in the upper part of figure 9, as a curve of longrun annual timber output over prospective stumpage-price level. Price, within the range considered, is seen to have but a small bearing upon the calculated output; and the higher the price, the smaller the bearing. What this upper curve in figure 9 would say is that it is not possible for consumers to get much more timber grown by offering to pay more for it—nor, within limits, will they sacrifice much timber by offering to pay less. This is because in the last analysis it takes growing stock to make growth. And, as brought out in chapter 2, the price level has negligible bearing upon the holding of growing stock by forest owners.

Interest rate.—The output-price relationship illustrated in the upper part of figure 9 is conceived to hold true when other things are equal—that is, when costs remain unchanged at the levels assumed. For example, interest rates are conceived to remain at the 3-, 6-, and 12-percent levels for the three major classes of forest owners, and the weighted average interest rate for all owners is 4 percent. At a higher guiding rate of interest, the output-price curve would lie below the one drawn. At a guiding rate lower than 4 percent, the curve would lie above the present one.

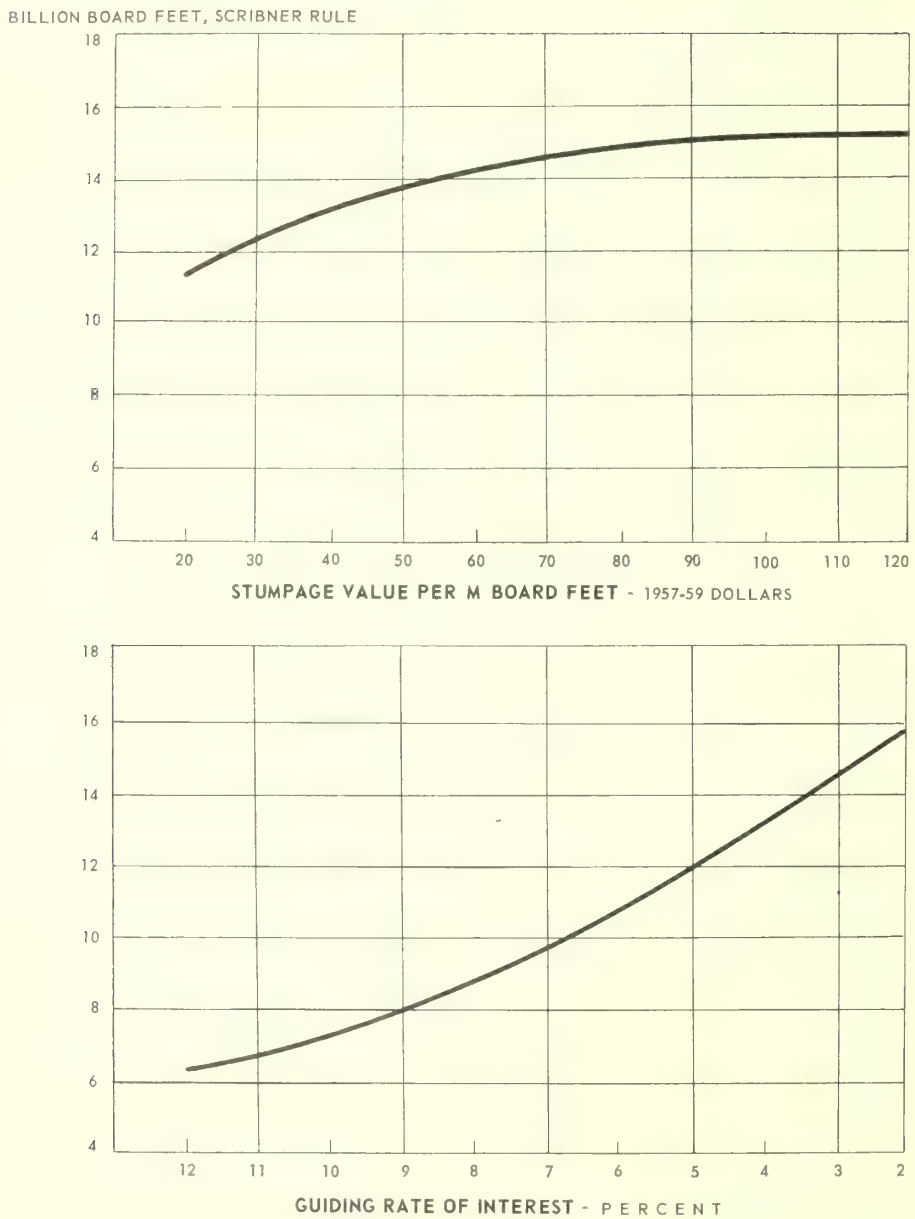


Figure 9.—Longrun potential annual timber output of the Douglas-fir subregion, in relation to stumpage value and to the guiding rate of interest.

The general relationship between longrun output and the guiding rate of interest is graphed in the lower part of figure 9. Here again, other things are conceived to be held the same. The prospective stumpage-price level is held at $40. The lower curve, like the upper one, is derived from five plotted points: At 4 percent, output is 13.1 billion board feet, as determined in table 18; at 3, 6, and 12 percent, outputs are found by multiplying the estimated total commercial forest acreage (considering the influence of interest rate upon land use) by the appropriate per acre output from table 15; at 2 percent, output is estimated by analogous procedure with additional allowance for fertilizer and improved regeneration programs, which begin to show a profit even at the $40 price level.

Since the guiding rate of interest works upon potential output through all the same influences as does price and since it exerts an additional effect through its control over growing stock and rotation length, it is not surprising to find that output, especially in the upper range, is considerably more sensitive to the rate of interest than to the price level. Indeed, it appears from figure 9 that larger output gains may be forthcoming from each successive lowering of the interest rate. At rates approaching zero, timber yields presumably approach the biological maximum attainable under an extremely intensive cultural regime.

Land management and use.—Finally, three alternative assumptions will be tested tn their effects upon longrun potential yield: (1) the assumption that on exploitively held forest lands, all special timber production efforts except forest protection will be abandoned; (2) the assumption that an additional million acres of National Forest lands will be reserved as vast recreational areas; (3) the assumption that this million acres will not be reserved and that a further million acres classed in the principal assumption as reserved will instead be available primarily for timber growing.

The small privately owned forest holdings have often been characterized as the crux of the forestry problem in the United States, referring to the fact that these holdings make up a large share of all the forest land, are for the most part exploitively managed, and are difficult to reach through forestry programs. In the Douglas-fir subregion, small holdings are nearly a fourth of all the commercial forest and consequently an object of interest.

The question of how much timber may be grown economically on the small holdings in Douglas-fir country has been explored. The longrun potentialities envisaged for them were, first, that nearly half of their acreage might be absorbed into larger holdings and thus come under conservative regimes of management and, second, that the remainder might be handled under the most intensive programs consistent with their owners' guiding rates of interest. Such programs may be thought of as requiring a good deal of extension effort on the part of public agencies and perhaps also wood-using industry—effort in the form of technical advice and assistance. By way of contrast, it may be well to estimate longrun timber-output potentialities in the absence of extension programs and in the absence of any special timber-management measures other than forest protection.

Since the question at issue here concerns not so much the small holdings as the properties in exploitive ownership (the counterpart of today's "crux of the

forest problem"), attention will be directed to the 2 million acres of commercial forest land assumed to remain in such ownership in the long run.

The potential annual output of the exploitively held properties in the absence of special effort (and with a price prospect of $40 per thousand) is estimated to be 160 million board feet, as against 457 million with the special effort (table 18). That is to say, the result of the effort might be, at most, about 300 million board feet of additional annual yield in the long run. Or, to look at the matter from the other viewpoint, the longrun loss in annual yield from a writeoff of the exploitively held forest properties might be as much as 300 million board feet, or 2-1/4 percent of the total. It is largely in the public values of this 300 million feet of timber that justification would ultimately be sought for public forestry programs directed at the exploitive owners.

As for the alternative assumptions about vast recreational areas—(a) that an extra million acres of forest will be reserved, and (b) that an extra million acres will be opened to timber management—the lands involved would be largely the poorer sites at the higher elevations. Indeed, it is assumed that in terms of the conifer type-sites, either of the million-acre aggregates would consist of 60-percent type-site 4 and the remainder type-sites 2 and 3, mostly the latter. With these acreage assumptions and the per acre yields of table 15, one may calculate that the loss of a million acres from the timber column, or the gain of a million acres, would in the long run amount to about 270 million board feet of output per year, or 2 percent of the total.

## What the Findings Imply

Although the long run as conceived in this study is a remote period, the interest of the region in this period is not remote but immediate, because the shape of things in the long run is being determined today by today's planning. It is a result of the long production span in forestry that major questions of the far future must be answered now. The questions of landownership in the long run, of land use, and most particularly of timber types, rotations, and output are current and live questions—policy issues of today and not of some vague tomorrow.

Consequently, it is of great and immediate interest to search out some of the implications of the longrun timber-output relationships developed in this study.

Problem of altering output.—The relationships important to analyze are those between output on the one hand and its major determinants on the other. These are the vital relationships because they must come into play in any effort by the community (that is, the industry, the State, or the Nation) to alter the supply outlook, either by deliberate measures or through the automatic devices of the economy.

What is involved in altering the supply outlook? Though 13.1 billion board feet is estimated to be an economic longrun level of timber yield under the principal assumptions of this study, higher figures may be considered by the community and, moreover, proposed as a goal. What is involved in reaching such a goal?

To raise timber output in the long run will involve a cost to the community. That is to say, it will mean a cost to the forest owner—a cost of forgoing returns (presumably at the guiding rate) from alternative investment-or-spending in favor of relatively low returns from the additional timber inventory needed to raise output. This cost is, in effect, a carrying charge or storage charge on the extra growing stock required to raise output. Forest owners will need to have in view a repayment from some source if they are to bear such a charge, for the amount may be considerable.

Approaching output through price.—What constitutes an effective method for raising timber output? For example, in the foregoing illustration, how could the community pay private forest owners an extra $500 million per year so as to obtain from these owners the additional production that $500 million would defray? Clearly, the community could not do it by spending the money in the forest products market. For if this should be attempted—that is, if demands for timber should rise—the probable outcome would be simply a much higher price for timber but very little more production of it, as the upper curve in figure 9 suggests. The extra $500 million, if it could be spent at all in the market, would merely be pocketed by those forest owners who were growing and cutting timber anyhow. Ultimately, the money would show up largely in profits from the holding of timberland and in increments in the value of such land. If owners foresaw that timber prices would stay at the new, high level, they would logically plan to cut about as much timber as before. Or, if the price rise should lead to anticipation of further increases, owners might well decide to cut less timber so as to accumulate some stocks and enhance their revenues later on. Thus the community would achieve just the opposite of what it intended with its cash outlays.

It is sometimes said that the law of supply and demand is the best forester, but surely this is to give the law undeserved credit. Through the price of the product, the law does indeed work to get more pulp and paper made, more lumber cut, and even more timber harvested. But when it comes to getting more wood grown, the law of supply and demand promises to be but an indifferent ally. Again, the cause of this is that the amount of wood grown depends greatly on the amount of growing stock held, and the latter depends very little on wood value, which for the forest owner is both a source of revenue and a countervailing source of cost.

Considering that high timber prices represent mainly a penalty for the wood-consuming community, and that continuously rising prices, though a stimulus to longrun output, entail costs out of all proportion to their benefits, there is much to be said in favor of stable, moderate prices such as have been assumed for the future in this report. Such a price scheme is most favorable to abundant timber consumption and can easily be compatible with abundant production. A community policy of holding timber prices down can be made effective in two general ways.

First, prices will be held down through efforts to increase timber output in the short run. The principal way to accomplish this without jeopardizing longrun

production is by an accelerated program of old-growth conversion and replacement by thrifty young-growth forests, which would mean primarily an increased cutting schedule for the public forests. Accomplishing such a program is a problem of the transition period.

Second, timber prices will be held down if the output of timber rises in the long run in response to nonprice influences. The principal such influence for the discussion of which this report has laid a foundation—and apparently the principal influence through which low-cost programs may work to raise production—is the forest owner's guiding rate of interest. The problem is to lower the guiding rates under which the commercial forest lands of the region are managed.

Approaching output through interest rates.—One way that guiding rates of interest are reduced is through transfers of forest properties from high rate owners to lower rate owners. It is assumed in this report that such transfers will proceed in the future through the initiative of the lower rate, stronger private owners. The assumed trends in ownership represent a gain in longrun timber-output potential and a loss in breadth of the private-land ownership base as the holding of land becomes concentrated in fewer hands. Such gains and losses from concentration are the factors that the community can weigh in order to determine its policy respecting forest ownership trends.

If the community proposes either to acknowledge or to promote the trend toward concentration in private forest ownership, then it has open to it various steps in extension education and in research which may make for more orderly and equitable land transfers. One of the most obvious of these steps concerns the land market, where the forces at work are concentrated. It consists of discovering and encouraging the adoption of procedures whereby the market can measure and reflect all the values in timberland, especially the value of slow-pay-out investments, as in the planting and early care of the forest stand. Thereby the forest owner may be encouraged to go ahead with such investments even if the permanence of his tenure is much in doubt.

Besides changes in ownership, the other way that guiding rates of interest are reduced is through a rate-reduction trend for individual owners or classes of owners. The analysis of determinants of the guiding rate provides a checklist of the conditions under which a forest owner's rate may be reduced:

1. A maturing of the economy and consequent decline in the prospective rate of return from alternative investments.

2. A rise in the real incomes of the forest owners whose guiding rates are determined by consumption alternatives. The owners in question here are primarily the farm woodland owners. Any agricultural policy that favors the retirement of marginal farms and the development and consolidation of productive commercial farms will promote timber conservation and high outputs in the long run.

3. The institution of public controls or subsidies to intensify the timber-management practices of forest owners in the exploitive and intermediate groups.

4. Measures to raise fringe benefits and transfer costs of forestry investments. Public policies that foster the use of net income taxation in preference to other forms of taxation for raising public revenues will tend to promote intensive timber management on private lands.

5. Measures to reduce the risks of timber management. Risks associated with forest property taxation—the threat of higher rates or of disadvantageous changes in the terms of taxation—may be important here. Early adoption of neutral methods of taxation will help to reduce risk. Also helpful will be research and action programs that will reduce prospective timber losses from insects, disease, and fire.

All such measures may, of course, cost something. And inevitably there is a critical level of output beyond which the opportunity costs will exceed the rewards. The alternatives to pushing beyond the longrun critical level of timber output in the Douglas-fir subregion include getting more wood from other parts of the United States up to their own critical levels of output, importing more wood and wood products, and using more substitutes for wood.

# Chapter 4

## Timber Yields During Transition

The report has been concerned up to this point largely with the timber yields of the long run. An economic potential output of some 13.1 billion board feet and 400 million additional cubic feet per year has been worked out for the Douglas-fir subregion under assumed conditions of land use and forest management. The forces that control the longrun potential have been studied, and some measures that might change longrun output have been inferred. Generally, the guiding rate of interest appears to be highly influential in timber production, while timber prices have comparatively little effect.

The longrun potential is in the nature of a destination or target. Since the long run is distant, some may view the target with detachment or unconcern. But when it comes to the means and the route for reaching the longrun level of production, that is a different matter, of obviously immense and immediate interest to everyone who has a stake in the Douglas-fir industry. The report turns now to this vital matter of the transition period—the period of conversion to a young-growth ceonomy.

Three principal questions are involved:

1. What are the current forest acreage and timber volume in the Douglas-fir subregion and how are the prospects for the transition period affected by their current disrtibution among districts, forest type sites, classes of ownership, and, most especially, stand-age classes?

2. If present trends in forest management and timber cutting should continue, what changes would be most likely to occur in timber output and growing stock during the transition period in the Douglas-fir subregion, and what problems might result?

3. What are the possibilities, if forest management were intensified faster than present trends suggest and if the subregion's old-growth timber were converted to young growth more rapidly than is now intended, and what problems are likely to arise during such an accelerated transition?

The analysis aimed at the foregoing questions will be built around a sawtimber-management objective, including a sawtimber rotation, and not a wood-fiber objective and rotation. It will use as its principal unit of timber measurement the board foot (net Scribner scale) rather than the cubic foot. Since the analysis concerns the immediate and near future, this conformity with today's viewpoint and conventions is believed to be appropriate.

### Current Forest Inventory

For the purpose of looking at current forest conditions and their bearing upon the transition, reference will be made again to the basic inventory prepared for

this study and already introduced in tables 1, 2, and 8. The inventory is tabulated in detail in Appendix A, where also the compilation procedure is explained. The period to which the data refers is the "decade of 1950's." For convenience, the date of reference will be interpreted here to be the end of the decade and the figures cited in the present tense.

Since the time of this analysis, additional inventories have been made; however, preliminary new totals as of this publication are basically in agreement with the figures shown in this report.

Growing stock.—The subregion's 25-3/4 million acres of commercial forest land support some 647 billion board feet of sawtimber, an average of about 25,000 board feet per acre. It is interesting to compare this current growing stock, which supports an annual growth of roughly 5 billion board feet and an annual cut of about 11.5 billion, with the growing stock estimated to be required for producing the subregional annual yield of 13.1 billion board feet in the long run. Under the specified management assumptions, the longrun estimate of required growing stock is 203 billion board feet, or an average of 8,200 board feet per acre. That is to say, the estimated growing stock for the long run in the Douglas-fir subregion is 31 percent of today's growing stock. Approximately the same proportion holds for each of the subregion's three districts. The comparable percentages for the four conifer type-sites are:

| | Required growing stock in percent of actual |
|---|---|
| Type-site 1 | 41 |
| Type-site 2 | 36 |
| Type-site 3 | 18 |
| Type-site 4 | 11 |

The degree of excess growing stock increases as one moves from the better to the poorer sites (i.e., from lower to higher elevations and from easier to more difficult terrain), largely because this is the general order in which the sites have been entered for exploitation and in which conversion to young growth has progressed. Type-sites 3 and 4 include most of the subregion's remaining commercial forest that is poorly supplied with roads.

The excess of growing stock is further described by the age distribution of the subregion's live sawtimber. For this purpose, it is necessary to exclude 53 billion board feet of timber in uneven-aged stands and to turn attention to the remainder of the sawtimber inventory, some 594 billion feet, amounting to more than nine-tenths of the total. This saw-timber in even-aged stands is about equally divided among the four 100-year age classes that reach from 1 to 400 years. If 50-year age classes are considered, again the distribution is roughly equal, save that 51- to 100-year stands account for much more than their proportionate share of the sawtimber, while 1- to 50-year stands contain much less. The whole distribution of live, even-aged sawtimber by age class is laid out in figure 10, where it is represented by the crosshatched cluster of bars.

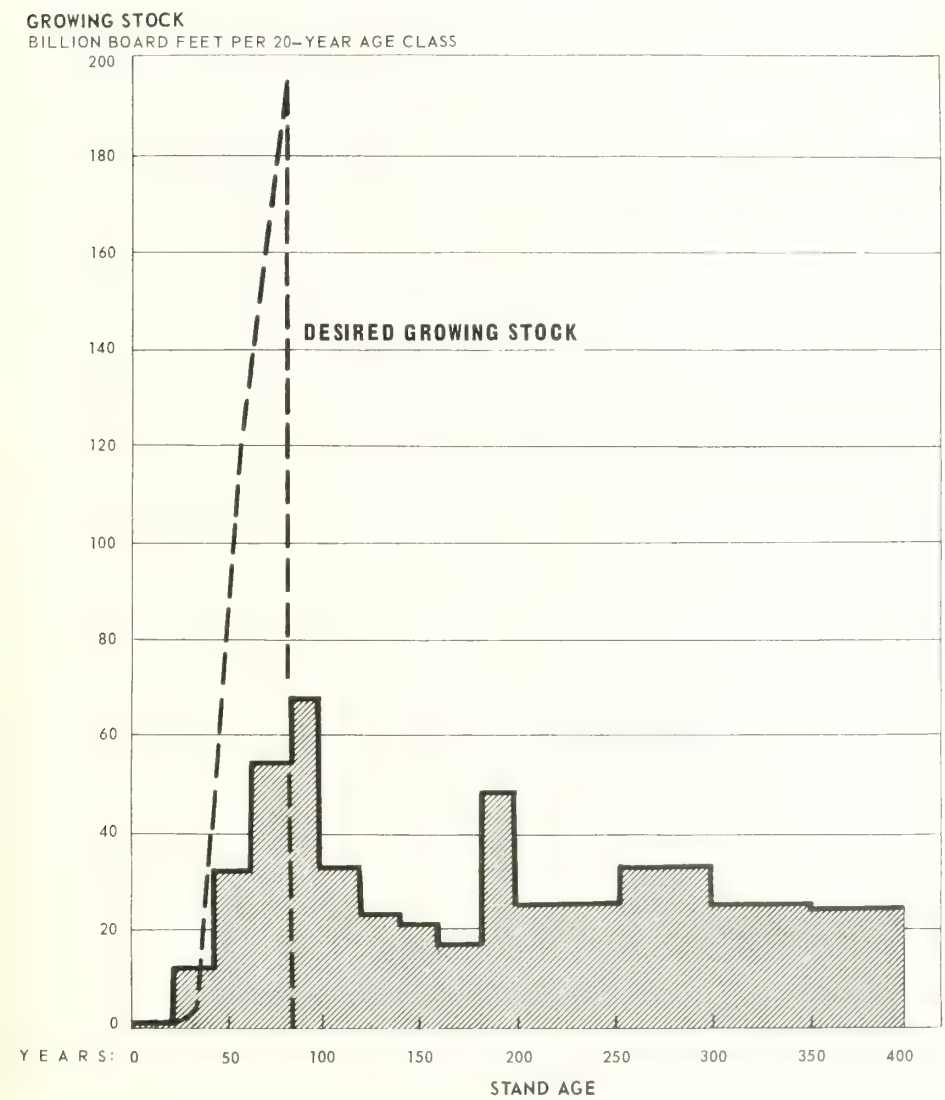


Figure 10.—Sawtimber growing stock by stand-age class in the Douglas-fir subregion, decade of 1950's.

Suppose, to make the story simple and not exaggerate the excess of growing stock, that the forest were all of medium site (index 140), conservatively held and intensively managed on an indicated sawtimber rotation of 80 years. The potential output of such a forest—i.e., the economic potential—would be in the neighborhood of 17 billion board feet per year. The sawtimber growing stock required to sustain such an output, about 240 billion board feet, is traced by the broken line in figure 10. It is little more than a third of the growing stock being carried today. Thus are pointed up the two great timber-management tasks of the transition period:

1. Pursuing the best program for liquidating the excess growing stock. For illustration of what this task involves for the various owners, note that the 491 billion board feet of timber in excess of 80-year age (see fig. 10) is distributed as follows, in percentage, among classes of ownership:

| | |
|---|---|
| Private holdings: | |
| Large | 27 |
| Medium | 4 |
| Small | 7 |
| Public Holdings: | |
| National Forest | 46 |
| Other Federal | 10 |
| Other | 6 |
| All holdings | 100 |

2. Packing the required growing stock into the age classes where it is needed. This task is represented in figure 10 by the uncrosshatched portion of the area under the broken line. In practice, it will take the form of getting tree regeneration and carrying out subsequent cultural measures on lands from which overage timber has been removed. Its aim will be to raise the efficiency of the subregion's sawtimber growing stock—today's annual net growth amounts to less than 1 percent of stock; even the cut is but 2 percent of stock; a managed growing stock such as that outlined in figure 10 would yield 6 or 7 percent per year.

The question of how fast to push ahead with the required shifts and changes of the transition—how fast to raise the efficiency of capital by moving to a young-growth economy—is perhaps the principal forestry question in Douglas-fir country today.

Commercial forest acreage.—In some ways more revealing of transition problems than the distribution of growing stock is the distribution of commercial forest land acreage. Acreage is the more permanent feature of the forest, and the ideal age-class distribution of acreage is much simpler to describe than is that of growing stock.

Age-class distributions of commercial forest acreage in the Douglas-fir subregion and its three districts are summarized in figure 11 and detailed in figures 16 through 19 and tables 25-28 Appendix A. Some of the highlights are as follows:

On the 20-1/2 million acres of stocked, even-aged coniferous commercial forest in the subregion, the youngest stands are in general the most extensive and the oldest stands the least. The distribution by 50-year age class is approximately:

| Age class (years): | Percent |
|---|---|
| 1-50 | 39 |
| 51-100 | 22 |
| 101-150 | 8 |
| 151-200 | 8 |
| 201-250 | 7 |
| 251-300 | 7 |
| 301-350 | 5 |
| 351 or more | 4 |
| All classes | 100 |

The form of this distribution is attributable mainly to the history of cutting and fire, in addition to the natural life span of conifers on the various sites. Most of the forest originated within the past 100 years—in fact, within the past 50—because that is when most of the timber cutting and burning were concentrated.

The prominence of forests that are in the first century of life is a general feature of each of the three districts in the Douglas-fir subregion and of virtually every category of private forest. It is a feature, also, of some of the public catgeories, especially those other than National Forest—and in the Columbia River district, even of National Forest. That is to say, forest conversion from old growth to young growth is progressing everywhere, but it has progressed farthest on private lands and least far on the National Forests.

As one moves southward from the Puget Sound district, where the concentration of forest acreage in the younger age classes is very pronounced, he finds in general less and less such concentration, and certainly the least in the Southwest Oregon district (fig. 11). He is moving southward over the same route taken by the lumber industry and by the fires that followed lumbering or introduced farming. He is, in effect, observing the influence upon forest structure of the progressively different history illustrated in figure 2 and in figure 4. He is observing the progress of forest conversion from old growth to young growth.

Another aspect of the same history and progress is discovered when one compares the four conifer type-sites, as in figures 16 through 19. He finds everywhere a regular graduation from type-site 1 through type-site 4, with the former showing the greatest concentration in young stands, the latter the least. Generally speaking, type-site 1 has always been the most accessible forest and certainly the most attractive for exploitation and conversion. And type-site 4 has been the least so.

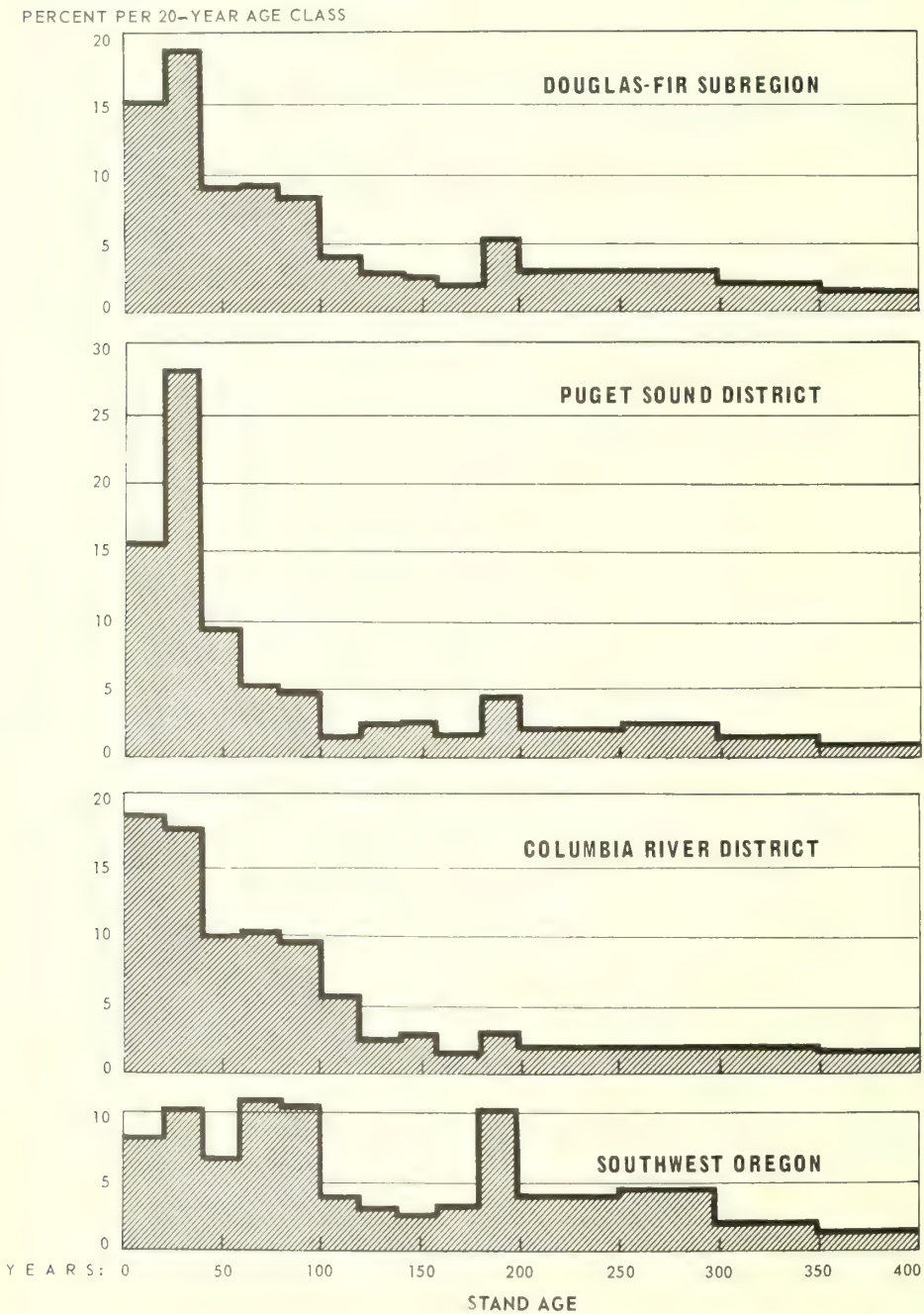


Figure 11.—Distribution of even-aged coniferous commercial forest area by stand-age class, Douglas-fir subregion and its three districts, decade of 1950's.

Within the important age class 1 to 100 years, stands between 1 and 40 years are most prominent; six-tenths of such stands are on private holdings in the Puget Sound and Columbia River districts. Young forests from 21 to 40 years of age are especially extensive. Nearly half of these are in the Puget Sound district. Most of them became established on cutovers, both old and recent, during the 1930's, when a tightening of fire control greatly reduced the burning and reburning of such lands (see fig. 4). Forests in the age class from 1 to 20 years, which is the next most extensive 20-year age class in the Douglas-fir subregion, are somewhat concentrated in the Columbia River district, where the effects of better fire control were felt later than in the district to the north.

Besides the forests in the age classes from 1 to 100 years, the older stands, that range for the most part, up to 400 years, are impressively extensive. There are more than 8 million acres of these older forests in the Douglas-fir subregion. In the Puget Sound and Columbia River districts, they make up a little more than one-third of the total acreage of stocked, even-aged coniferous forests. In the Southwest Oregon district, they are more than one-half of the total. Their prominence is clearly apparent in figure 11. In the same figure, the 181- to 200-year age class is seen to stand out to some extent in all districts and most conspicuously in the Southwest Oregon. The widely occurring forests of this age appear to have originated in the wake of great conflagrations.

Significance of forest inventory.—What is the significance of the timber inventory with respect to the transition era that lies ahead? The inventory stands at the center of certain key issues and questions about the transition, such as whether there is a gap in the age-class distribution that threatens to interrupt or curtail regional timber output, whether such a gap exists for particular forest owners or classes of owners, and how the age-class distribution affects the choice of a conversion period.

The current distributions of forest acreage by stand-age class may be compared with those of ideally regulated forests. For this purpose, it is well to take note of nonstocked forest land acreage in addition to the stocked. This is done in figure 12, where nonstocked acreage is represented by means of a bar, 20 years wide, to the left of the zero-year mark. Such a charting implies that this acreage will be restocked in the course of the next 20 years. Figure 12 excludes forests of type-site 5 in order to focus attention on the comparatively homogenous softwoods. The omission is believed to have negligible effect on the analysis which follows.

If, in figure 12, the same simplifying assumption is made as was used in figure 10—that an average 80-year rotation is to be followed on all lands—then, if the forest were perfectly regulated, 25 percent of its total acreage would fall in each of the four 20-year age classes up to 80 years. This ideal age-class distribution is marked out with broken lines in the upper left graph of figure 12.

It is seen in figure 12 that where there is insufficient forest acreage in stands below rotation age to fill the rectangle representing the ideal and where there

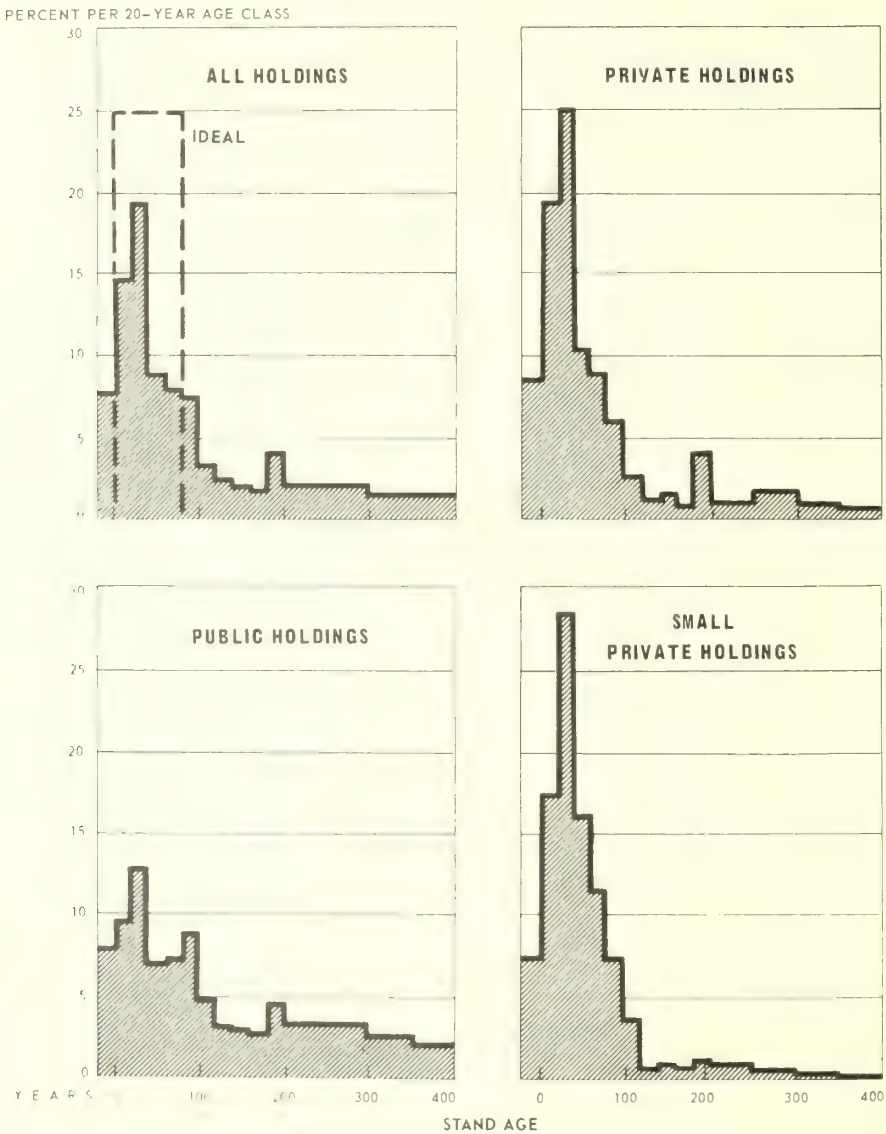


Figure 12.—Distribution of even-aged coniferous commercial forest area by stand-age class on four classes of forest holdings in the Douglas-fir subregion, decade of 1950's.

are at the same time stands above rotation age, the latter can be harvested to make up the insufficiency of the former. Indeed, if there are no nonstocked areas and if none of the age classes under rotation age exceeds its ideal share of total acreage (if no bars project through the top of the rectangle), then the overage areas are just enough to make up the insufficiency. In this case, an ideal age-class distribution can be reached by the end of one rotation. And even during this rotation, there need be no departure from even flow—that is, from generally equal or increasing outputs from period to period of 5 or 10 years or more.

The foregoing propositions are abstract. The ideal distribution of age classes is more a general planning guide than a specific goal for any forest owner or for any community. Even in countries where forests have been under management for generations, few examples of mathematically exact forest regulation are to be seen. In practice, the rotation is a general and flexible idea, and so is age-class arrangement. On any forest property or group of properties, cuts vary from year to year and from decade to decade; the quantity of timber currently reaching rotation age is seldom identical with the current cut; and the discrepancy is remedied by harvesting older or younger stands. However, the ideas of rotation length, age-class distribution, and even flow are still very useful for analyzing the problems of transition in the Douglas-fir subregion.

Even flow of timber.—It appears that the circumstances which may lead to a marked departure from even flow during the transition period are these:

1. An excessively great acreage of forest (much more than its share in the ideal distribution) in an age class of stands younger than rotation age. This situation has developed on some individual forest properties and in some widespread communities after rapid timber cutting or extensive forest burning.

2. An excessively long rotation—one which reduces the ideal percentage of area in any age class to the point where the commonest class becomes overabundant.

It appears in the upper left chart of figure 12 that in the Douglas-fir subregion as a whole, in all classes of ownership combined, there is no threat of reduction in the flow of timber during the period of transition as a result of a gap in age distribution. The same is true of all public holdings as a group and of all private holdings. Small private holdings appear to include an excessive acreage of stands in the 21- to 40-year age class—until it is realized that these holdings will surely be carried on a shorter rotation than 80 years. On medium sites, the average saw log rotation foreseen for small private forest holdings even in the long run amounts to only 56 years, which implies an ideal age-distribution rectangle 56 years wide and 36 percent high (i.e., each 20-year age class occupying 36 percent of the commercial forest acreage)—more than high enough to accommodate the bars in the lower right corner of figure 12. The corresponding data for major classes of ownership are these:

| | Average rotation (in years) | Rectangle height (in percent) |
|---|---|---|
| Private holdings: | | |
| Large | 77 | 26 |
| Medium | 63 | 32 |
| Small | 56 | 36 |
| Public holdings: | | |
| National Forest | 80 | 25 |
| Other | 75 | 27 |

On the basis of these data, and referring now to figures 15-18 in Appendix A, one concludes that there is evidence of gaps here and there in all major categories of forest ownership except National Forest. Gaps are found primarily in the Puget Sound district, secondarily in the Columbia River district. Few if any indications of gaps are to be discovered in these summary charts for National Forests in any part of the subregion or for any class of ownership in the southwest Oregon district. However, it is clear that abnormalities in the age-class distribution appear more and more widely as one examines smaller and smaller categories of forest. Surely, marked departures from the ideal are very common among individual forest holdings—at least among private forest properties outside the southern part of the subregion. It is this condition of the forest resource that has led to widespread discussion and some trial of the cooperative sustained-yield-unit idea.

In the last analysis, there is just one sort of remedy for the raw material problems that abnormal age-class distributions create for individual manufacturers of wood products. The remedy is to take advantage of the subregion's gap-free aggregate age class arrangement. This, in turn, means relying upon the market and upon transportation facilities to let the overages that exist on some holdings go to cancel out the underages on others. Much of the flow of overage toward underage is a flow of public timber to private firms. Since this is the direction of the flow anyhow, the issue resolves itself into that of the volume of flow.

## Yields if Present Trends Continue

Attention is turned now to the second of the three questions asked at the beginning of this chapter: If present trends in forest management and timber cutting should continue, what changes might occur in timber output and growing stock, and what might be the contingent problems? In an effort to answer this question, the inventory for the 1950's was taken as the starting point for a careful and detailed bookkeeping projection to the year 2000, followed by a summary projection thence for an additional forest rotation period.

For the detailed projection, estimates of timber growth (see Appendix B) and timber cut were used to calculate successive timber inventories applying to the years 1970, 1980, 1990, and 2000. These inventories, of acreage and of the quantity of sawtimber, were worked up separately for each stand-age class in each

ownership and type-site class in each of the districts of the Douglas-fir subregion. The estimated harvests were recorded in the same detail. Allowances were made for the changes in land use and forest ownership, the "principal assumption" postulated in chapter 2, and for forest losses through fire, storm, and other destructive agencies.

The detailed projection was based upon assumptions that were developed in consultation with private and public forestry officials within the subregion. It was assumed that on much of the public forest the allowable cuts current in 1960 would continue in effect and be fully harvested.[3] On private forests, the basic harvest would be a given percentage of current inventory, ranging from 2 percent on large private holdings in the Puget Sound district to 6 percent on small private holdings in the Southwest Oregon. Thus provision was made for distinguishing between slow cutters and fast cutters on the basis of holding size and of district. It was assumed that the basic cut of each owner would be taken mostly from his oldest remaining age classes of forest, but allowance was made for some harvest cutting in younger stands.

Besides the basic cut of timber on private and public lands, an additional cut resulted from the assumption that a thinning regime would be introduced over the years. The assumptions made about thinning were, for example, that among large private holdings on type-sites 1 and 2, 50 percent of the young-growth forest would be in a thinning program by 1990. For public forests, the assumed percentage was 25. Necessary transportation and marketing developments would accompany and make possible these advances in silviculture. They would go hand in hand, also, with a growing program of salvage cuts, prelogging, relogging, and the like for older stands, designed to recapture timber lost through mortality and to tighten standards of timber utilization on both private and public lands.

The summary projection that was applied to the decades following 2000 was kept consistent, so far as possible, with the assumptions of the detailed projection for earlier decades. The procedure was essentially that of a trial projection followed by an area-volume check such as is used in setting an allowable cut for a forest property. Yield estimates, but no forecasts of ending inventory, were obtained in this projection.

A fuller explanation of the projection assumptions and procedures, as well as detailed tables and graphs of the results, is made in Appendix C.

The detailed projection for the period 1960-2000 will be taken up first, beginning with the question of yields. A summary of estimated outputs, decade by decade, for the Douglas-fir subregion as a whole is given in table 20. The data are subdivided by district in tables 52 through 54, Appendix C.

[3] Between the time this study was begun and January 1963, the total allowable cut for public lands was increased by about 10 percent to reflect shortened rotations, better inventory and growth data, and other factors. This new level of cut could not be incorporated into the details of this report. This actual increase is believed to be within the context of the present trends projection. For example, the 3,028 million board feet of output shown in table 20 for the National Forests during the decade of the 1960's compares favorably with the National Forest allowable cut of 2,987 million board feet as of January 1963.

Yields over time, 1960-2000.—Looking, for the moment, only at the "all" line in each decade group in table 20, one observes that if present trends continue, the output from all commercial forest lands of the subregion—the harvest cuts, thinnings, salvage, and the rest, both live and dead timber—will average about 11.6 billion board feet per year during the four decades, 1960-2000. This figure is in terms of standing timber equivalent, the same terms used throughout this report except in the very few cases which are clearly noted.

The 40-year average output of 11.6 billion board feet is close to the actual average annual cut in the decade of the 1950's, 11.5 billion feet in terms of standing timber. Indeed, the projected output holds fairly steady from decade to decade, especially after the first decade, which is the only one of the four in which the average annual output is expected to deviate from the 40-year average by more than 4 percent.

Table 20. — Prospective annual output of timber in the Douglas-fir subregion if present trends continue, by decade, ownership class, and source of output, 1960-2000

(In million board feet)

| Source of output | Private holdings | | | | Public holdings | | | | Public and private holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | All | National Forest | Other Federal | Other | All | |
| **DECADE OF 1960's** | | | | | | | | | |
| Reduction of inventory | 1,064 | 526 | 1,374 | 2,964 | 1,717 | 581 | 104 | 2,402 | 5,366 |
| Replaced by growth | 3,085 | 191 | 951 | 4,227 | 1,063 | 476 | 505 | 2,044 | 6,271 |
| Salvage | 327 | 43 | 28 | 398 | 248 | 113 | 39 | 400 | 798 |
| All | 4,476 | 760 | 2,353 | 7,589 | 3,028 | 1,170 | 648 | 4,846 | 12,435 |
| **DECADE OF 1970's** | | | | | | | | | |
| Reduction of inventory | 609 | 303 | 884 | 1,796 | 1,543 | 570 | 18 | 2,131 | 3,928 |
| Replaced by growth | 3,339 | 241 | 744 | 4,324 | 1,297 | 505 | 728 | 2,531 | 6,855 |
| Salvage | 282 | 17 | -- | 299 | 322 | 118 | 33 | 472 | 770 |
| All | 4,230 | 561 | 1,628 | 6,419 | 3,162 | 1,193 | 779 | 5,134 | 11,553 |
| **DECADE OF 1980's** | | | | | | | | | |
| Reduction of inventory | 92 | 221 | 687 | 1,000 | 1,590 | 469 | 35 | 2,094 | 3,094 |
| Replaced by growth | 3,924 | 215 | 543 | 4,682 | 1,243 | 644 | 771 | 2,658 | 7,340 |
| Salvage | 200 | 8 | 1 | 209 | 377 | 134 | 42 | 553 | 762 |
| All | 4,216 | 444 | 1,231 | 5,891 | 3,210 | 1,247 | 848 | 5,305 | 11,196 |
| **DECADE OF 1990's** | | | | | | | | | |
| Reduction of inventory | 474 | 53 | 281 | 808 | 1,421 | 628 | 69 | 2,118 | 2,926 |
| Replaced by growth | 4,036 | 320 | 560 | 4,916 | 1,490 | 511 | 770 | 2,771 | 7,687 |
| Salvage | 164 | 3 | 1 | 168 | 362 | 107 | 38 | 507 | 675 |
| All | 4,674 | 376 | 842 | 5,892 | 3,273 | 1,246 | 877 | 5,396 | 11,288 |

It should, of course, be noted that the rather level trend foreseen for timber harvests is in terms of total board feet of physical volume. The character of wood in the board foot is not expected to be just the same at the end of the period as at the beginning. Nor will the uses and value of a board foot be just the same, nor the quantity of other wood produced along with a board foot. The changes expected are the normal and usual changes of a transition era.

Yields related to geography and ownership.—Beneath the somewhat steady board foot output projected for the whole forest lie some compensating trends. An upward trend is anticipated for the Puget Sound district as more and more young-growth timber ascends to merchantability and as its output is augmented by thinnings. In the other two districts, output is expected to decline somewhat, thus shifting the gravity center of the wood industry slightly northward again after many decades to the southward.

Also, some exchange between private and public cuts is anticipated. In recent years, close to 70 percent of the subregion's timber output has derived from private lands. A continuation of current trends would result in a persistent reduction in the private cut, notably in the Southwest Oregon and Columbia River districts, and a corresponding increase in the public cut in all districts. The percentages of total output by decade are:

| Decade: | Private cut | Public cut |
|---|---|---|
| 1960's | 61 | 39 |
| 1970's | 56 | 44 |
| 1980's | 53 | 47 |
| 1990's | 52 | 48 |

The projected decline in the private timber harvest is paced by the small holdings. Here, shrinkage both in total acres and in growing stock per acre is expected to trim the output by half during the 30 years between the 1960's and the 1990's. The reduction will be severest in the Southwest Oregon district and least in the Puget Sound. Such prospects are in line with the landownership and management changes foreseen in chapter 2.

Projected increases in the public timber harvest are shared rather uniformly among districts and classes of holdings. These increases, it must be noted, are calculated despite the assumption that there will be no change in allowable cuts of old growth if present trends continue. The increases stem from the assumption of steady improvements in silviculture and wood utilization.

Composition of yields.—The total timber output trend projected for the period 1960-2000 also contains some compensating changes in the composition of the cut. Some of the major changes anticipated are the following:

1. A shift in the regional harvest toward a larger percentage of young-growth timber as the liquidation of old growth progresses.

2. A closely related shift away from cutting not replaced by timber growth toward cutting that is replaced—that is, a movement toward sustained yield management based on growth. This shift is reflected in the first two lines within each decade group in table 20 (and in tables 43 through 45). Here, "reduction in inventory" signifies cutting (both thinning and final harvest) that comes out of inventory in the sense that it serves to reduce total inventory in that ownership class in any district. "Replaced by growth" signifies cutting (again, both thinning and final harvest) that is replaced by growth and so does not reduce inventory in the

district. It is well to remark that the "reduction in inventory" figures may exceed the inventory reductions that are actually anticipated, since they omit net changes in inventory in any ownership class and district. Likewise, "replaced by growth" is only that part of growth expected to be cut and not necessarily the total growth.

3. A marked rise in the quantity of thinnings in young growth and of various salvage and utilization cuts other than the main harvest in old growth. The thinning projections, which are included in the "reduction in inventory" and "replaced by growth" lines of table 20 (and of tables 43 through 45) are separately displayed in table 21. The projections of the other types of cut are recorded in the "salvage lines" of the tables. In the total amount of all such cuttings, the Columbia River district is expected to lead the others in all decades.

Table 21. — Prospective annual timber output from thinnings in the Douglas-fir subregion and its three districts if present trends continue, by ownership class and decade, 1960-2000

(In million board feet)

| Decade | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DOUGLAS-FIR SUBREGION** | | | | | | | | | |
| 1960's | 106 | 17 | 31 | 154 | 9 | 3 | 8 | 20 | 174 |
| 1970's | 287 | 38 | 53 | 378 | 25 | 18 | 45 | 88 | 466 |
| 1980's | 557 | 58 | 68 | 683 | 32 | 28 | 87 | 147 | 830 |
| 1990's | 1,063 | 90 | 62 | 1,215 | 63 | 58 | 113 | 234 | 1,449 |
| **PUGET SOUND DISTRICT** | | | | | | | | | |
| 1960's | 45 | 3 | 12 | 60 | 1 | (1) | 6 | 7 | 67 |
| 1970's | 109 | 8 | 20 | 137 | 5 | 1 | 23 | 29 | 166 |
| 1980's | 205 | 14 | 25 | 244 | 7 | 1 | 38 | 46 | 290 |
| 1990's | 331 | 40 | 12 | 383 | 15 | 1 | 39 | 55 | 438 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | | | |
| 1960's | 44 | 13 | 18 | 75 | 8 | 1 | 2 | 11 | 86 |
| 1970's | 143 | 23 | 26 | 192 | 18 | 8 | 21 | 47 | 239 |
| 1980's | 286 | 34 | 35 | 355 | 22 | 12 | 48 | 82 | 437 |
| 1990's | 486 | 40 | 36 | 562 | 39 | 27 | 68 | 134 | 696 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | | | |
| 1960's | 17 | 1 | 1 | 19 | (1) | 2 | (1) | 2 | 21 |
| 1970's | 35 | 7 | 7 | 49 | 2 | 9 | 1 | 12 | 61 |
| 1980's | 66 | 10 | 8 | 84 | 3 | 15 | 1 | 19 | 103 |
| 1990's | 246 | 10 | 14 | 270 | 9 | 30 | 6 | 45 | 315 |

[1] Less than ½ million board feet.

4. A general increase in timber growth, not only aggregate as reflected in table 20, but also per forest acre (table 22) and percent of growing stock (table 23). On public lands, aggregate growth rises from 30 percent of that on all holdings in the 1960's to 36 percent in the 1990's. This is the consequence mainly of cleaning up and clearing away old timber and of launching a thinning program for younger stands. However, the growth rates achieved by the year 2000 are still far below par and indicate need to accelerate management if higher level of growth is to be reached. On private lands, growth rates are markedly higher than on public. The differences revealed in tables 22 and 23 among the three classes of private holdings result in part from a purely statistical cause: the shifts in private forest ownerships that were built into the projection.

From a glance back over the four major points that have been made about changes in composition of the cut if present trends continue, it is obvious that the topic of growth, in one guise or another, dominates these points. Growth is what will permit the total harvest to be maintained. And the level of growth—that is, the efficiency of the timber resource—stands out as the principal issue when present trends are evaluated.

Forest inventory in 2000.—If the yields anticipated under a continuation of present trends are indeed harvested, then one may expect the forest of the Douglas-fir subregion to change very greatly in timber quantity and in composition by the year 2000.

Table 22. — Prospective annual timber growth per acre of commercial forest land in the Douglas-fir subregion and its three districts if present trends continue, by ownership class and decade, 1960-2000

(In board feet)

| Decade | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DOUGLAS-FIR SUBREGION** | | | | | | | | | |
| 1960's | 470 | 182 | 253 | 352 | 141 | 187 | 258 | 172 | 265 |
| 1970's | 454 | 204 | 163 | 329 | 173 | 206 | 418 | 225 | 279 |
| 1980's | 520 | 209 | 140 | 382 | 166 | 256 | 407 | 230 | 308 |
| 1990's | 453 | 416 | 233 | 396 | 201 | 205 | 401 | 238 | 320 |
| **PUGET SOUND DISTRICT** | | | | | | | | | |
| 1960's | 469 | 295 | 239 | 365 | 152 | 257 | 212 | 179 | 290 |
| 1970's | 442 | 411 | 205 | 357 | 167 | 268 | 420 | 261 | 318 |
| 1980's | 557 | 360 | 167 | 422 | 162 | 238 | 406 | 251 | 353 |
| 1990's | 449 | 376 | 151 | 365 | 147 | 265 | 372 | 230 | 310 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | | | |
| 1960's | 542 | 188 | 347 | 420 | 158 | 267 | 336 | 212 | 320 |
| 1970's | 569 | 134 | 180 | 384 | 222 | 287 | 435 | 276 | 332 |
| 1980's | 590 | 153 | 149 | 416 | 209 | 335 | 436 | 275 | 348 |
| 1990's | 499 | 406 | 205 | 415 | 271 | 275 | 441 | 306 | 363 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | | | |
| 1960's | 328 | 60 | 69 | 194 | 103 | 134 | -- | 110 | 146 |
| 1970's | 255 | 87 | 52 | 174 | 99 | 153 | 266 | 126 | 146 |
| 1980's | 340 | 58 | 69 | 253 | 103 | 213 | 180 | 149 | 193 |
| 1990's | 378 | 590 | 483 | 406 | 134 | 159 | 276 | 148 | 258 |

The sawtimber inventory projected for the year 2000 is about 465 billion board feet—little more than seven-tenths of the inventory in the decade of 1950's. The projected inventory for the Puget Sound district is down 15 percent; for the Columbia River district, down 26 percent; for the Southwest Oregon district, down 45 percent. The heaviest percentage reductions are generally in the categories of small and medium-size private holdings. National Forest inventories in the subregion are reduced in about the same proportion as all holdings together, some 30 percent. Such a reduction, with approximately sustained output, means a 40- to 45-percent rise in efficiency of the growing stock.

Table 23. — Prospective annual timber growth as a percentage of growing stock in the Douglas-fir subregion and its three districts if present trends continue, by ownership class and decade, 1960-2000

(In percent)

| Decade | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DOUGLAS-FIR SUBREGION** | | | | | | | | | |
| 1960's | 2.1 | 1.6 | 3.3 | 2.3 | 0.4 | 0.8 | 1.5 | 0.6 | 1.2 |
| 1970's | 2.4 | 2.0 | 2.4 | 2.3 | .5 | 1.0 | 2.3 | .8 | 1.3 |
| 1980's | 3.0 | 2.1 | 2.9 | 2.9 | .5 | 1.4 | 2.1 | .8 | 1.5 |
| 1990's | 2.9 | 3.8 | 3.0 | 3.0 | .7 | 1.2 | 2.0 | .9 | 1.6 |
| **PUGET SOUND DISTRICT** | | | | | | | | | |
| 1960's | 2.0 | 2.4 | 3.4 | 2.3 | 0.4 | 1.8 | 0.9 | 0.6 | 1.3 |
| 1970's | 2.1 | 3.5 | 2.8 | 2.3 | .5 | 1.8 | 3.5 | .9 | 1.5 |
| 1980's | 2.8 | 3.1 | 2.3 | 2.7 | .5 | 1.5 | 1.6 | .9 | 1.7 |
| 1990's | 2.4 | 3.4 | 2.2 | 2.4 | .5 | 1.8 | 1.5 | .9 | 1.5 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | | | |
| 1960's | 2.2 | 1.4 | 3.9 | 2.5 | 0.4 | 1.0 | 2.9 | 0.6 | 1.3 |
| 1970's | 2.6 | 1.1 | 2.3 | 2.5 | .6 | 1.2 | 3.3 | .9 | 1.4 |
| 1980's | 3.0 | 1.4 | 2.4 | 2.8 | .6 | 1.5 | 2.9 | .9 | 1.6 |
| 1990's | 2.9 | 3.5 | 3.5 | 3.0 | .8 | 1.4 | 2.7 | 1.0 | 1.7 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | | | |
| 1960's | 1.8 | 0.9 | 1.3 | 1.7 | 0.4 | 0.6 | 1.3 | 0.5 | 0.8 |
| 1970's | 2.2 | 1.5 | 1.6 | 2.1 | .4 | .8 | 1.6 | .6 | .9 |
| 1980's | 3.9 | 1.0 | 3.1 | 3.7 | .4 | 1.2 | 1.1 | .7 | 1.3 |
| 1990's | 5.1 | 6.2 | 12.2 | 6.0 | .6 | 1.0 | 2.0 | .8 | 1.8 |

How the commercial forest acreage will be distributed by stand-age class in 2000 if present trends continue, and how the distribution compares with that of today, is summarized for the Douglas-fir subregion in figure 13, and for the three districts, in figures 19-24 in Appendix C. These figures treat only of stocked, coniferous forests. It is estimated that 10 percent of the commercial forest acreage in 2000 will be nonstocked. And 7 percent will be in hardwood cover. A great deal of this hardwood forest will be on small private holdings in the north and central districts of the subregion.

Figure 13 makes clear how strongly the forest age distributions are expected to shift toward the younger classes during the era 1960-2000, particularly on private holdings. By the end of the 40 years, each of the three classes of private holdings will show aggregate age-class distributions somewhat resembling the

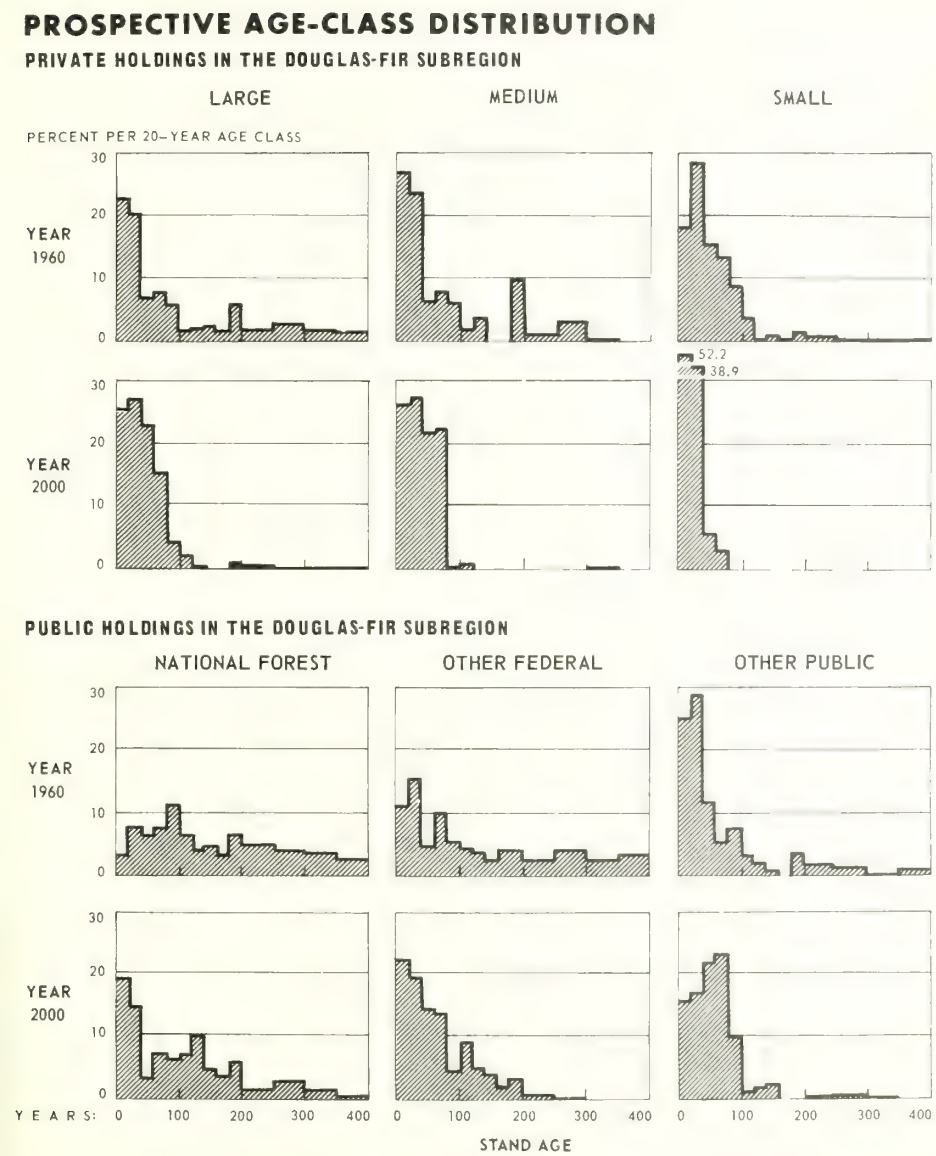


Figure 13.—Distribution of even-aged coniferous commercial forest area by stand-age class for major classes of ownership, Douglas-fir subregion, 1960 and 2000, if present trends continue.

ideal distributions represented in the tabulation on page 92. Non-Federal public holdings, too, will be approaching an ideal distribution in the aggregate. On the National Forests, however, more than half of the area will still be in stands older than 100 years.

Yields after 2000.—The summary projection made for the years beyond 2000 affords a general view of the far outlook if present trends continue. The results of the projection are presented in table 24 and charted in figure 14. Data from table 20 have been added in order to show the entire series of 11 decades studied in the detailed and summary projections.

From the last column in table 24 and in figure 14 it appears that the even tenor of total output promised for the next four decades can be sustained thereafter—indefinitely, it would seem—if present trends in timber programs continue. Potential total outputs after the year 2000 are, in fact, more stable than those preceding. They climb gradually, reaching the longrun annual level of 13.1 billion board feet by the year 2070.

The projected aggregate outputs from the major categories of private and of public lands are also quite steady from decade to decade as they move in the direction of the longrun potential. The same tendencies are to be traced, also, within the separate districts of the Douglas-fir subregion (not shown in table 24). Minor fluctuations here and there in the projected output have no real significance, since they could have been eliminated in the bookkeeping process by slightly different allocations of allowable cuts between adjacent decades.

Table 24. — Prospective annual output of timber in the Douglas-fir subregion if present trends continue, by ownership class and decade, 1960-2070

(In billion board feet)

| Decade | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| 1960's | 4.5 | 0.8 | 2.3 | 7.6 | 3.0 | 1.2 | 0.6 | 4.8 | 12.4 |
| 1970's | 4.2 | .6 | 1.6 | 6.4 | 3.2 | 1.2 | .8 | 5.2 | 11.6 |
| 1980's | 4.2 | .5 | 1.2 | 5.9 | 3.2 | 1.2 | .9 | 5.3 | 11.2 |
| 1990's | 4.7 | .4 | .8 | 5.9 | 3.3 | 1.2 | .9 | 5.4 | 11.3 |
| 2000's | 5.2 | .4 | .9 | 6.5 | 3.1 | 1.2 | 1.1 | 5.4 | 11.9 |
| 2010's | 5.4 | .4 | .8 | 6.6 | 3.3 | 1.2 | 1.2 | 5.7 | 12.3 |
| 2020's | 5.5 | .4 | .6 | 6.5 | 3.4 | 1.3 | 1.3 | 6.0 | 12.5 |
| 2030's | 5.5 | .4 | .6 | 6.5 | 3.6 | 1.3 | 1.3 | 6.2 | 12.7 |
| 2040's | 5.5 | .4 | .6 | 6.5 | 3.7 | 1.4 | 1.3 | 6.4 | 12.9 |
| 2050's | 5.5 | .3 | .7 | 6.5 | 3.9 | 1.0 | 1.3 | 6.2 | 12.7 |
| 2060's | 5 5 | .3 | .9 | 6.7 | 4.0 | 1.1 | 1.3 | 6.4 | 13.1 |

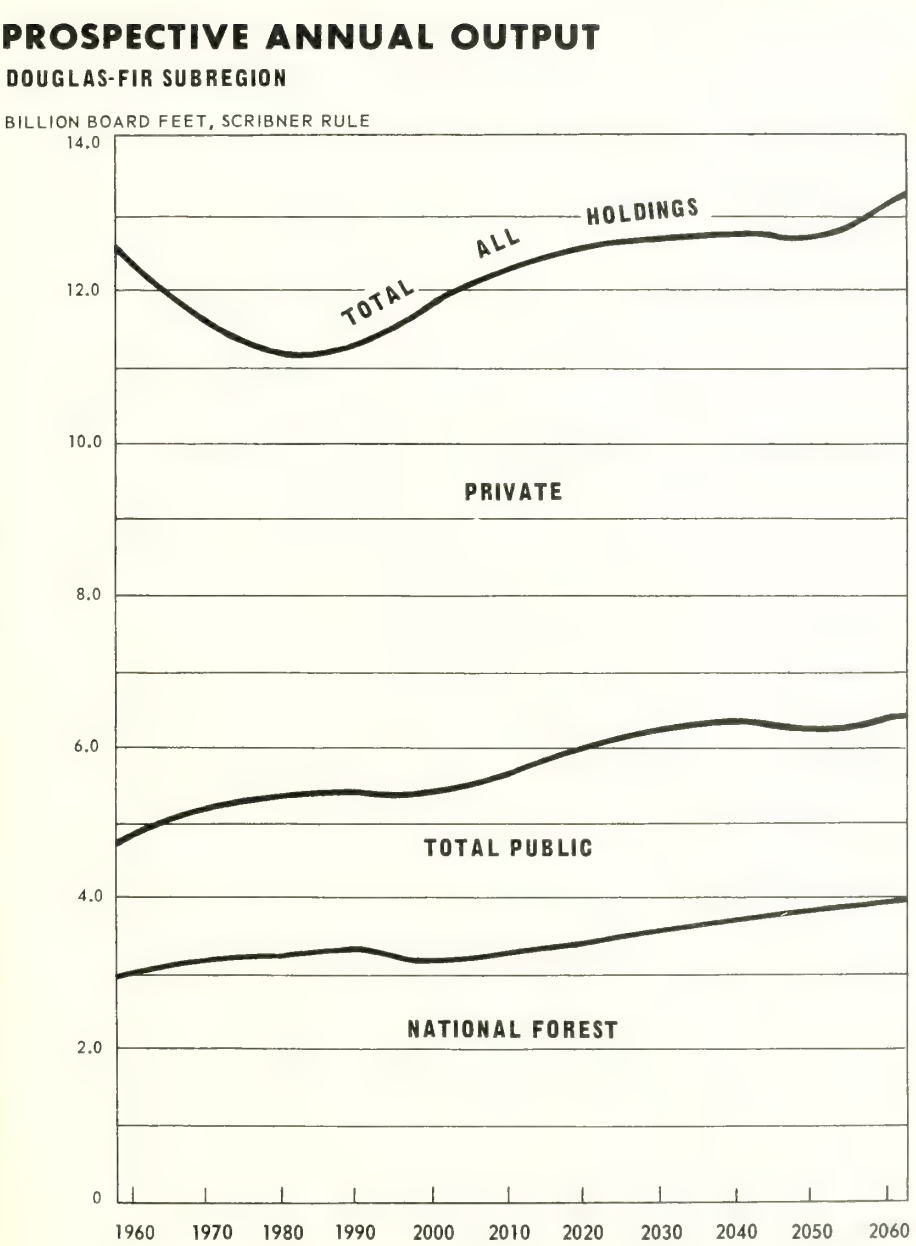


Figure 14.—Prospective annual output of timber in the Douglas-fir subregion if present trends continue, by ownership class, 1960-2070.

## Problems and Opportunities of the Transition Period

The purpose of this final section is to examine briefly the last of the three questions asked in the introduction to this chapter. What are the possibilities if forest management were intensified faster than present trends suggest and if the subregion's old-growth timber were converted to young-growth more rapidly than is now intended, and what problems are likely to arise during such an accelerated transition?

There are, of course, many alternatives to the output that is in prospect with present trends. Future cutting levels can be varied over a rather wide range, depending particularly upon cutting policies relating to old-growth stands. Management programs can be of greatly different intensities.

Possibilities for increasing timber output depend, for example, on the degree to which reforestation technology is further developed and investments in planting accelerated beyond the levels assumed in Appendix C. Such action could assure prompter replacement of harvested stands and early restocking of the extensive backlog of cutover nonstocked lands in the region. Improved planting techniques are of critical importance in making possible an increase in cuts.

More rapid development of thinning, salvage cutting, prelogging, relogging, or other types of cutting associated with intensive management could also permit larger timber harvests in both the short and long run. Such intensification of utilization will depend upon existence of markets for the material produced. This in turn will depend in part on the rate at which old-growth timber is liquidated and the general growth of demand for lumber and other wood products in the Nation's markets.

More rapid cutting of old-growth timber also could lead to a greater aggregate cut of timber, both over the next few decades and over the coming century. This could only be achieved, however, at the expense of disrupting the timber industry in the future when it would be necessary to lower available supply to the longrun regulated forest potential, and only if successful conversion to well-stocked young stands could be assured.

In the case of forests with a considerable excess of age classes beyond rotation age, a more rapid harvest of old growth could produce a greater total yield over time than with present trends because the growth of young stands is greater than in old-growth forests. One trial projection of such accelerated conversion, for example, indicated that total yields during the next century might be increased as much as 12 percent by such cutting policies.

By shifting capital out of low efficiency uses to higher efficiency uses in forestry or other business alternatives—acceleration of cutting—the total level of regional and national income and employment might well be increased. Within the region's forest industries, expanding plant capacity and accelerating the cut at this time would, of course, lead in turn to later declines in log supplies.

Accelerating the cut of old-growth timber in the short run also would undoubtedly act to depress prices of stumpage and manufactured products to some

degree. On the one hand, this could well prevent or delay the utilization of thinnings and other material of relatively low value. On the other hand, such accelerated cutting might well strengthen the incentive of private forest owners to reduce their own cut and to use more public timber instead; this in turn could lead to deferment of cutting in the younger age classes and a building up of the age classes that must provide the log supplies of the future. The rate of market expansion for products of the Douglas-fir region is, of course, of critical importance in determining impacts of accelerated cutting within the region and in competing areas.

Adequate consideration of the many possible modifications of present management and cutting trends in the Douglas-fir region and evaluation of the varied impacts on the region's economy that might result from alternative policies are of large practical significance. Such questions, however, must necessarily be the subject of future analyses that will supplement this initial study of the timber situation and outlook in the Douglas-fir region.

# Appendix A
## Forest Inventory

Tables 25-32 show commercial forest acreage, total and per acre board foot volume (Scribner rule) of live sawtimber, and total and per acre cubic foot volume of all growing stock by type-site and ownership classes in the Douglas-fir subregion and each of its three districts as mapped in figure 1. Tables 25-32, on acreage, are further subdivided by stand-age class, as are figures 15-18, which illustrate percentages of forest land area.

For the most part, the data apply to the year of most recent Forest Survey inventory in each county inventoried since 1953 and to the late 1950's in the case of other counties. The resulting period of reference is termed "decade of 1950's."

The terms used in the tables are to be interpreted according to the standard definitions of the Forest Survey, with the exception of "land class" and "type-site."

"Land class" is a subdivision of nonstocked areas into (1) burns and old cutovers and (2) recent cutovers.

"Type-site" is a subdivision of all commercial forest lands into five groups on the basis of forest type and site class: Type-site 1 includes forests of the Douglas-fir, western hemlock, Sitka spruce, western redcedar, and sugar pine types on Douglas-fir sites I and II and forests of the ponderosa pine type on pine sites I and II. Type-site 2 includes the same group of forest types on Douglas-fir site III and ponderosa pine sites III and IV. Type-site 3 includes the same group of forest types on Douglas-fir sites IV and V and ponderosa pine sites V and VI. Type-site 4 includes all other conifer types—notably the true fir types, fir-mountain hemlock, Engelmann spruce, western larch, and western white and lodgepole pines—on all sites. Type-site 5 includes hardwood forests on all sites. These definitions may be arranged in tabular form as follows:

| Type-site | Douglas-fir, western hemlock, Sitka spruce, western redcedar, and sugar pine forest types | Ponderosa pine forest type | Other conifer forest types—e.g., true fir, fir-mountain hemlock, Engelmann spruce, western larch, western white pine, lodgepole pine | Hardwood forest types |
|---|---|---|---|---|
| 1 | Douglas-fir sites I and II | Ponderosa pine sites I and II | None | None |
| 2 | Douglas-fir site III | Ponderosa pine sites III and IV | None | None |
| 3 | Douglas-fir sites IV and V | Ponderosa pine sites V and VI | None | None |
| 4 | None | None | All sites | None |
| 5 | None | None | None | All sites |

The first four type-sites also include nonstocked commercial forest lands attributed to them by the method described hereinafter.

The following steps were taken in developing the inventory:

Of the 38 counties in the Douglas-fir subregion, 20 counties, well distributed geographically and believed to be representative of forest conditions, were designated as inventory counties. Every sample plot cluster examined in the field on the most recent Forest Survey of each inventory county was classified by stand-size, type-site, ownership, and stand-age classes. To supplement the field sample, which covered primarily sawtimber and poletimber stands, a sample of seedling and sapling stands and nonstocked areas was taken in the office on forest type and site maps. Again, every sample point was classified by forest stand size, type-site, ownership, and stand age (or, for nonstocked areas, land class). The forest type attributed to a nonstocked sample point was the type of the nearest area stocked with conifers.

The stand-size, type-site, ownership, and stand-age or land-class information for each plot cluster and sample point was tabulated along with the total commercial forest acreage, total board foot volume, and total cubic foot volume of growing stock represented by each cluster or point. From the tabulations for each district was computed the percentage of the total forest acreage, board foot volume, and cubic foot volume in each ownership and stand-size class that fell into each type-site and age (or land) class.

An inventory was drawn up for each district of the total commercial forest acreage, total board foot volume of sawtimber, and total cubic foot volume of growing stock by class of ownership and stand-size class. The inventory was taken from Forest Survey records. For all counties resurveyed since 1953, the records were accepted without change. For most other counties, the records were brought up to date by bookkeeping methods designed to allow for interim changes in forest area, ownership, and stand-size class, and in timber volumes as a result of growth and depletion. These inventory totals were then subdivided by type-site and age (or land) classes in accordance with the percentages derived from the analysis of plot clusters and sample points. Finally, the data for all stand-size classes were combined to provide estimates of forest acreage and timber volume by district, type-site class, ownership class, and stand-age (or land) class.

The great detail to which the inventory has been carried has one disadvantage: that data in some of the resulting categories are based upon very few sample plots and, consequently, may be wide of the mark and must be accepted with caution. In general, the smaller the acreage in any forest category (tables 25-32, the larger the error to which any data for that category are subject.

Table 25. — Area of commercial forest land, by type-site, ownership, and stand-age classes, Douglas-fir subregion, decade of 1950's

(In thousand acres)

ALL TYPE-SITE CLASSES

| Land class or stand age | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| Burns and old cutovers | 210 | 36 | 222 | 112 | 134 | 211 | 925 |
| Recent cutovers | 248 | 156 | 219 | 222 | 125 | 67 | 1,037 |
| 1-20 years | 1,086 | 395 | 1,038 | 223 | 247 | 596 | 3,585 |
| 21-40 years | 1,148 | 405 | 1,680 | 516 | 350 | 574 | 4,673 |
| 41-60 years | 309 | 115 | 939 | 436 | 104 | 249 | 2,152 |
| 61-80 years | 355 | 105 | 672 | 491 | 214 | 108 | 1,945 |
| 81-100 years | 260 | 89 | 431 | 679 | 149 | 144 | 1,752 |
| 101-120 years | 89 | 26 | 199 | 369 | 98 | 63 | 844 |
| 121-140 years | 116 | 50 | 28 | 249 | 84 | 40 | 567 |
| 141-160 years | 129 | -- | 60 | 284 | 54 | 16 | 543 |
| 161-180 years | 61 | -- | 51 | 215 | 93 | 1 | 421 |
| 181-200 years | 297 | 129 | 72 | 387 | 84 | 70 | 1,039 |
| 201-250 years | 206 | 41 | 148 | 744 | 138 | 89 | 1,366 |
| 251-300 years | 354 | 106 | 88 | 624 | 224 | 62 | 1,458 |
| 301-350 years | 262 | 12 | 47 | 578 | 136 | 10 | 1,045 |
| 351 years or older | 223 | 10 | 9 | 363 | 175 | 49 | 829 |
| Uneven aged | 95 | 68 | 218 | 1,001 | 163 | 40 | 1,585 |
| All classes | 5,448 | 1,743 | 6,121 | 7,493 | 2,572 | 2,389 | 25,766 |
| **TYPE-SITE 1** | | | | | | | |
| Burns and old cutovers | 116 | 19 | 89 | 6 | 16 | 134 | 380 |
| Recent cutovers | 189 | 61 | 94 | 21 | 44 | 10 | 419 |
| 1-20 years | 703 | 201 | 436 | 65 | 93 | 290 | 1,788 |
| 21-40 years | 387 | 104 | 491 | 37 | 36 | 250 | 1,305 |
| 41-60 years | 194 | 49 | 339 | 53 | 8 | 95 | 738 |
| 61-80 years | 229 | 68 | 229 | 187 | 159 | 82 | 954 |
| 81-100 years | 135 | 45 | 178 | 265 | 40 | 96 | 759 |
| 101-120 years | 37 | 13 | 29 | 91 | 46 | -- | 216 |
| 121-140 years | 17 | -- | 13 | 17 | 3 | 30 | 80 |
| 141-160 years | 26 | -- | -- | 32 | -- | 8 | 66 |
| 161-180 years | 29 | -- | -- | 27 | 33 | -- | 89 |
| 181-200 years | 190 | 21 | 28 | 45 | 72 | -- | 356 |
| 201-250 years | 56 | -- | 30 | 66 | 13 | 5 | 170 |
| 251-300 years | 231 | 24 | 23 | 77 | 112 | -- | 467 |
| 301-350 years | 120 | 3 | -- | 122 | 72 | 5 | 322 |
| 351 years or older | 83 | 3 | 9 | 87 | 66 | 15 | 263 |
| Uneven aged | 37 | 7 | 74 | 130 | 54 | 31 | 333 |
| All classes | 2,779 | 618 | 2,062 | 1,328 | 867 | 1,051 | 8,705 |
| **TYPE-SITE 2** | | | | | | | |
| Burns and old cutovers | 73 | 17 | 99 | 22 | 42 | 67 | 320 |
| Recent cutovers | 54 | 83 | 89 | 41 | 60 | 15 | 342 |
| 1-20 years | 302 | 144 | 378 | 100 | 106 | 171 | 1,201 |
| 21-40 years | 446 | 88 | 505 | 115 | 152 | 177 | 1,483 |
| 41-60 years | 79 | 33 | 240 | 107 | 55 | 52 | 566 |
| 61-80 years | 90 | 21 | 251 | 114 | 44 | 23 | 543 |
| 81-100 years | 105 | 8 | 125 | 187 | 47 | 33 | 505 |
| 101-120 years | 43 | 9 | 46 | 110 | 10 | 13 | 231 |
| 121-140 years | 79 | -- | 13 | 60 | 52 | 5 | 209 |
| 141-160 years | 42 | -- | 31 | 65 | 23 | 5 | 166 |
| 161-180 years | 23 | -- | 17 | 28 | 45 | 1 | 114 |
| 181-200 years | 85 | -- | 24 | 74 | 6 | 28 | 217 |
| 201-250 years | 64 | 6 | 41 | 164 | 89 | -- | 364 |
| 251-300 years | 31 | 76 | 26 | 116 | 86 | 20 | 355 |
| 301-350 years | 97 | -- | 13 | 164 | 10 | -- | 284 |
| 351 years or older | 49 | 7 | -- | 124 | 76 | 34 | 290 |
| Uneven aged | 46 | 37 | 40 | 258 | 51 | 5 | 437 |
| All classes | 1,708 | 529 | 1,938 | 1,849 | 954 | 649 | 7,627 |

Table 25. — Area of commercial forest land, by type-site, ownership, and stand-age classes, Douglas-fir subregion, decade of 1950's—Continued

(In thousand acres)

| Land class or stand age | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| **TYPE-SITE 3** | | | | | | | |
| Burns and old cutovers | 17 | -- | 27 | 31 | 62 | 5 | 142 |
| Recent cutovers | -- | 5 | 36 | 114 | 21 | 21 | 197 |
| 1-20 years | 18 | 8 | 40 | 22 | 31 | 17 | 136 |
| 21-40 years | 88 | 106 | 300 | 190 | 125 | 115 | 924 |
| 41-60 years | 32 | 3 | 136 | 160 | 35 | 70 | 436 |
| 61-80 years | 36 | 8 | 143 | 119 | 3 | -- | 309 |
| 81-100 years | 20 | 25 | 120 | 148 | 50 | 14 | 377 |
| 101-120 years | 9 | -- | 109 | 101 | 40 | 49 | 308 |
| 121-140 years | 9 | 50 | 2 | 95 | -- | 5 | 161 |
| 141-160 years | 59 | -- | 29 | 137 | 31 | -- | 256 |
| 161-180 years | -- | | 23 | 95 | 13 | -- | 131 |
| 181-200 years | 9 | 108 | 20 | 138 | 5 | 11 | 291 |
| 201-250 years | 73 | 29 | 61 | 251 | 33 | 49 | 496 |
| 251-300 years | 73 | 6 | 39 | 252 | 23 | 27 | 420 |
| 301-350 years | 44 | 8 | 34 | 165 | 54 | 5 | 310 |
| 351 years or older | 91 | -- | | 125 | 33 | -- | 249 |
| Uneven aged | - | 23 | 55 | 337 | 52 | -- | 467 |
| All classes | 578 | 379 | 1,174 | 2,480 | 611 | 388 | 5,610 |
| **TYPE-SITE 4** | | | | | | | |
| Burns and old cutovers | 4 | -- | 7 | 53 | 14 | 5 | 83 |
| Recent cutovers | 5 | 7 | -- | 46 | -- | 21 | 79 |
| 1-20 years | 2 | -- | -- | 17 | -- | -- | 19 |
| 21-40 years | 3 | 16 | 14 | 126 | 7 | 3 | 169 |
| 41-60 years | 4 | 1 | -- | 90 | 3 | -- | 98 |
| 61-80 years | -- | 8 | 2 | 45 | 3 | 1 | 59 |
| 81-100 years | -- | 4 | -- | 71 | -- | -- | 75 |
| 101-120 years | -- | 4 | | 63 | 2 | -- | 69 |
| 121-140 years | 8 | -- | -- | 75 | 29 | -- | 112 |
| 141-160 years | 2 | -- | -- | 49 | -- | 3 | 54 |
| 161-180 years | 9 | -- | -- | 64 | 2 | -- | 75 |
| 181-200 years | 13 | -- | -- | 129 | 1 | 31 | 174 |
| 201-250 years | 13 | 6 | 16 | 262 | 3 | 35 | 335 |
| 251-300 years | 19 | -- | -- | 179 | 3 | 15 | 216 |
| 301-350 years | 1 | 1 | -- | 127 | -- | -- | 129 |
| 351 years or older | -- | -- | -- | 27 | -- | -- | 27 |
| Uneven aged | 10 | 1 | 1 | 264 | 2 | -- | 278 |
| All classes | 93 | 48 | 40 | 1,687 | 69 | 114 | 2,051 |
| **TYPE-SITE 5** | | | | | | | |
| 1-20 years | 61 | 42 | 184 | 19 | 17 | 118 | 441 |
| 21-40 years | 224 | 91 | 370 | 48 | 30 | 29 | 792 |
| 41-60 years | -- | 29 | 224 | 26 | 3 | 32 | 314 |
| 61-80 years | -- | -- | 47 | 26 | 5 | 2 | 80 |
| 81-100 years | -- | 7 | 8 | 8 | 12 | 1 | 36 |
| 101-120 years | -- | -- | 15 | 4 | -- | 1 | 20 |
| 121 years or older | 3 | -- | 11 | 6 | -- | -- | 20 |
| Uneven aged | 2 | -- | 48 | 12 | 4 | 4 | 70 |
| All classes | 290 | 169 | 907 | 149 | 71 | 187 | 1,773 |

## Table 26. — Area of commercial forest land, by type-site, ownership, and stand-age classes, Puget Sound district, decade of 1950's

(In thousand acres)

**ALL TYPE-SITE CLASSES**

| Land class or stand age | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| Burns and old cutovers | 69 | 7 | -- | 32 | 27 | -- | 135 |
| Recent cutovers | 95 | 27 | 17 | -- | -- | 41 | 180 |
| 1-20 years | 456 | 48 | 332 | 67 | 13 | 220 | 1,136 |
| 21-40 years | 607 | 145 | 925 | 174 | 54 | 310 | 2,215 |
| 41-60 years | 130 | 36 | 294 | 85 | 13 | 137 | 695 |
| 61-80 years | 127 | 22 | 139 | 61 | 19 | 8 | 376 |
| 81-100 years | 72 | 16 | 69 | 93 | 10 | 59 | 319 |
| 101-120 years | 8 | -- | 17 | 35 | -- | 49 | 109 |
| 121-140 years | 52 | -- | 2 | 78 | 3 | 25 | 160 |
| 141-160 years | 84 | -- | 1 | 89 | -- | -- | 174 |
| 161-180 years | 29 | -- | 11 | 78 | -- | -- | 118 |
| 181-200 years | 110 | 15 | 13 | 100 | 1 | 41 | 280 |
| 201-250 years | 21 | 27 | 6 | 251 | -- | 81 | 386 |
| 251-300 years | 119 | -- | 42 | 227 | 3 | 42 | 433 |
| 301-350 years | 68 | 6 | -- | 252 | -- | -- | 326 |
| 351 years or older | 95 | -- | -- | 120 | 4 | 25 | 244 |
| Uneven aged | -- | 14 | 48 | 3 | 5 | 25 | 95 |
| All classes | 2,142 | 363 | 1,916 | 1,745 | 152 | 1,063 | 7,381 |

**TYPE-SITE 1**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Burns and old cutovers | 28 | 7 | -- | -- | -- | -- | 35 |
| Recent cutovers | 95 | 20 | -- | -- | -- | -- | 115 |
| 1-20 years | 302 | 25 | 105 | 22 | -- | 59 | 513 |
| 21-40 years | 140 | 3 | 245 | 3 | 3 | 118 | 512 |
| 41-60 years | 58 | 9 | 91 | 1 | -- | 32 | 191 |
| 61-80 years | 72 | 14 | 18 | -- | -- | -- | 104 |
| 81-100 years | 60 | -- | 11 | 18 | -- | 59 | 148 |
| 101-120 years | 8 | -- | -- | 5 | -- | -- | 13 |
| 121-140 years | 4 | -- | -- | 5 | 3 | 25 | 37 |
| 141-160 years | 20 | -- | -- | 19 | -- | -- | 39 |
| 161-180 years | 20 | -- | -- | 19 | -- | -- | 39 |
| 181-200 years | 85 | 15 | 1 | 17 | -- | -- | 118 |
| 201-250 years | 4 | -- | -- | 1 | -- | -- | 5 |
| 251-300 years | 41 | -- | -- | 18 | -- | -- | 59 |
| 301-350 years | 8 | -- | -- | 21 | -- | -- | 29 |
| 351 years or older | 4 | -- | -- | 24 | -- | -- | 28 |
| Uneven aged | -- | -- | -- | -- | 3 | 25 | 28 |
| All classes | 949 | 93 | 471 | 173 | 9 | 318 | 2,013 |

**TYPE-SITE 2**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Burns and old cutovers | 28 | -- | -- | -- | 9 | -- | 37 |
| Recent cutovers | -- | -- | 12 | -- | -- | -- | 12 |
| 1-20 years | 111 | 15 | 138 | 33 | 8 | 79 | 384 |
| 21-40 years | 212 | 22 | 248 | 40 | 1 | 104 | 627 |
| 41-60 years | 60 | 26 | 55 | 16 | 7 | 29 | 193 |
| 61-80 years | 49 | -- | 59 | 32 | 16 | 8 | 164 |
| 81-100 years | -- | -- | 26 | 36 | -- | -- | 62 |
| 101-120 years | -- | -- | 17 | 25 | -- | -- | 42 |
| 121-140 years | 40 | -- | -- | 9 | -- | -- | 49 |
| 141-160 years | 21 | -- | 1 | 25 | -- | -- | 47 |
| 161-180 years | -- | -- | -- | 6 | -- | -- | 6 |
| 181-200 years | 23 | -- | -- | 28 | -- | -- | 51 |
| 201-250 years | 3 | -- | -- | 52 | -- | -- | 55 |
| 251-300 years | 9 | -- | 3 | 26 | -- | -- | 38 |
| 301-350 years | 20 | -- | -- | 49 | -- | -- | 69 |
| 351 years or older | -- | -- | -- | 38 | 4 | 25 | 67 |
| Uneven aged | -- | 14 | 21 | 1 | -- | -- | 36 |
| All classes | 576 | 77 | 580 | 416 | 45 | 245 | 1,939 |

Table 26. — Area of commercial forest land, by type-site, ownership, and stand-age classes, Puget Sound district, decade of 1950's—Continued

(In thousand acres)

| Land class or stand age | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| **TYPE-SITE 3** | | | | | | | |
| Burns and old cutovers | 13 | -- | -- | -- | 9 | -- | 22 |
| Recent cutovers | -- | -- | 5 | -- | -- | 21 | 26 |
| 1-20 years | 15 | 5 | 19 | 4 | 5 | 14 | 62 |
| 21-40 years | 50 | 79 | 219 | 74 | 30 | 73 | 525 |
| 41-60 years | 11 | 1 | 77 | 61 | 5 | 50 | 205 |
| 61-80 years | 6 | 8 | 38 | 27 | 3 | -- | 82 |
| 81-100 years | 12 | 9 | 24 | 18 | -- | -- | 63 |
| 101-120 years | -- | -- | -- | 5 | -- | 49 | 54 |
| 121-140 years | -- | -- | 2 | 23 | -- | -- | 25 |
| 141-160 years | 42 | -- | -- | 45 | -- | -- | 87 |
| 161-180 years | -- | -- | -- | 26 | -- | -- | 26 |
| 181-200 years | -- | -- | 12 | 25 | -- | 10 | 47 |
| 201-250 years | 13 | 22 | -- | 76 | -- | 49 | 160 |
| 251-300 years | 60 | -- | 39 | 99 | 3 | 27 | 228 |
| 301-350 years | 40 | 6 | -- | 95 | -- | -- | 141 |
| 351 years or older | 91 | -- | -- | 37 | -- | -- | 128 |
| Uneven aged | -- | -- | 12 | 2 | -- | -- | 14 |
| All classes | 353 | 130 | 447 | 617 | 55 | 293 | 1,895 |
| **TYPE-SITE 4** | | | | | | | |
| Burns and old cutovers | -- | -- | -- | 32 | 9 | -- | 41 |
| Recent cutovers | -- | 7 | -- | -- | -- | 20 | 27 |
| 1-20 years | 2 | -- | -- | 7 | -- | -- | 9 |
| 21-40 years | 3 | -- | 6 | 45 | 5 | 2 | 61 |
| 41-60 years | 1 | -- | -- | 5 | -- | -- | 6 |
| 61-80 years | -- | -- | -- | -- | -- | -- | -- |
| 81-100 years | -- | -- | -- | 20 | -- | -- | 20 |
| 101-120 years | -- | -- | -- | -- | -- | -- | -- |
| 121-140 years | 8 | -- | -- | 41 | -- | -- | 49 |
| 141-160 years | 1 | -- | -- | -- | -- | -- | 1 |
| 161-180 years | 9 | -- | -- | 27 | -- | -- | 36 |
| 181-200 years | 2 | -- | -- | 30 | 1 | 31 | 64 |
| 201-250 years | 1 | 5 | 6 | 122 | -- | 32 | 166 |
| 251-300 years | 9 | -- | -- | 84 | -- | 15 | 108 |
| 301-350 years | -- | -- | -- | 87 | -- | -- | 87 |
| 351 years or older | -- | -- | -- | 21 | -- | -- | 21 |
| Uneven aged | -- | -- | -- | -- | -- | -- | -- |
| All classes | 36 | 12 | 12 | 521 | 15 | 100 | 696 |
| **TYPE-SITE 5** | | | | | | | |
| 1-20 years | 26 | 3 | 70 | 1 | -- | 68 | 168 |
| 21-40 years | 202 | 41 | 207 | 12 | 15 | 13 | 490 |
| 41-60 years | -- | -- | 71 | 2 | 1 | 26 | 100 |
| 61-80 years | -- | -- | 24 | 2 | -- | -- | 26 |
| 81-100 years | -- | 7 | 8 | 1 | 10 | -- | 26 |
| 101-120 years | -- | -- | -- | -- | -- | -- | -- |
| 121 years or older | -- | -- | 11 | -- | -- | -- | 11 |
| Uneven aged | -- | -- | 15 | -- | 2 | -- | 17 |
| | 228 | 51 | 406 | 18 | 28 | 107 | 838 |

Table 27. — Area of commercial forest land, by type-site, ownership, and stand-age classes, Columbia River district, decade of 1950's

(In thousand acres)

ALL TYPE-SITE CLASSES

| Land class or stand age | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| Burns and old cutovers | 104 | 24 | 165 | 44 | 39 | 208 | 584 |
| Recent cutovers | 96 | 69 | 100 | 35 | 39 | 23 | 362 |
| 1-20 years | 531 | 275 | 521 | 137 | 132 | 366 | 1,962 |
| 21-40 years | 488 | 147 | 554 | 270 | 105 | 246 | 1,810 |
| 41-60 years | 133 | 79 | 507 | 238 | 40 | 111 | 1,108 |
| 61-80 years | 161 | 24 | 391 | 329 | 63 | 43 | 1,011 |
| 81-100 years | 140 | 69 | 128 | 472 | 40 | 57 | 906 |
| 101-120 years | 81 | 22 | 98 | 262 | 63 | 14 | 540 |
| 121-140 years | 64 | -- | 26 | 102 | 20 | 15 | 227 |
| 141-160 years | 45 | -- | 13 | 114 | 54 | 16 | 242 |
| 161-180 years | 32 | -- | 17 | 72 | 22 | -- | 143 |
| 181-200 years | 59 | 13 | 5 | 165 | 12 | -- | 254 |
| 201-250 years | 96 | 14 | 31 | 278 | 40 | 7 | 466 |
| 251-300 years | 105 | 39 | -- | 244 | 56 | 20 | 464 |
| 301-350 years | 100 | 6 | 24 | 290 | 37 | 10 | 467 |
| 351 years or older | 128 | 10 | 9 | 216 | 39 | 24 | 426 |
| Uneven aged | 78 | 54 | 120 | 293 | 81 | 12 | 638 |
| All classes | 2,441 | 845 | 2,709 | 3,561 | 882 | 1,172 | 11,610 |

TYPE-SITE 1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Burns and old cutovers | 80 | 12 | 72 | 5 | 16 | 134 | 319 |
| Recent cutovers | 56 | 26 | 68 | 13 | 22 | 9 | 194 |
| 1-20 years | 341 | 157 | 289 | 41 | 51 | 224 | 1,103 |
| 21-40 years | 236 | 72 | 195 | 29 | 26 | 131 | 689 |
| 41-60 years | 93 | 40 | 187 | 42 | 8 | 63 | 433 |
| 61-80 years | 90 | 3 | 162 | 179 | 27 | 25 | 486 |
| 81-100 years | 60 | 45 | 51 | 232 | 7 | 37 | 432 |
| 101-120 years | 29 | 13 | 6 | 82 | 13 | -- | 143 |
| 121-140 years | 13 | -- | 13 | 10 | -- | 5 | 41 |
| 141-160 years | 6 | -- | -- | 7 | -- | 8 | 21 |
| 161-180 years | 9 | -- | -- | 3 | -- | -- | 12 |
| 181-200 years | 18 | 6 | -- | 18 | 6 | -- | 48 |
| 201-250 years | 9 | -- | 6 | 37 | 13 | 5 | 70 |
| 251-300 years | 60 | 16 | -- | 35 | 13 | -- | 124 |
| 301-350 years | 62 | 3 | -- | 99 | 6 | 5 | 175 |
| 351 years or older | 79 | 3 | 9 | 60 | -- | 15 | 166 |
| Uneven aged | 22 | 7 | 28 | 62 | 47 | 5 | 171 |
| All classes | 1,263 | 403 | 1,086 | 954 | 255 | 666 | 4,627 |

TYPE-SITE 2

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Burns and old cutovers | 20 | 12 | 88 | 17 | 18 | 67 | 222 |
| Recent cutovers | 36 | 43 | 27 | 18 | 17 | 14 | 155 |
| 1-20 years | 163 | 85 | 146 | 62 | 66 | 91 | 613 |
| 21-40 years | 206 | 42 | 193 | 66 | 29 | 61 | 597 |
| 41-60 years | 19 | 7 | 133 | 71 | 15 | 23 | 268 |
| 61-80 years | 41 | 13 | 123 | 67 | 28 | 15 | 287 |
| 81-100 years | 72 | 8 | 45 | 127 | 14 | 5 | 271 |
| 101-120 years | 43 | 9 | 29 | 70 | 10 | 13 | 174 |
| 121-140 years | 39 | -- | 13 | 38 | 19 | 5 | 114 |
| 141-160 years | 21 | -- | 7 | 26 | 23 | 5 | 82 |
| 161-180 years | 23 | -- | 17 | 10 | 7 | -- | 57 |
| 181-200 years | 21 | -- | -- | 20 | 6 | -- | 47 |
| 201-250 years | 61 | 6 | -- | 57 | 24 | -- | 148 |
| 251-300 years | 22 | 17 | -- | 54 | 20 | 20 | 133 |
| 301-350 years | 33 | -- | 13 | 108 | 10 | -- | 164 |
| 351 years or older | 49 | 7 | -- | 71 | 6 | 9 | 142 |
| Uneven aged | 46 | 23 | 15 | 74 | 13 | 5 | 176 |
| All classes | 915 | 272 | 849 | 956 | 325 | 333 | 3,650 |

Table 27. — Area of commercial forest land, by type-site, ownership, and stand-age classes, Columbia River district, decade of 1950's—Continued

(In thousand acres)

| Land class or stand age | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| **TYPE-SITE 3** | | | | | | | |
| Burns and old cutovers | -- | -- | -- | 10 | -- | 2 | 12 |
| Recent cutovers | -- | -- | 5 | 4 | -- | -- | 9 |
| 1-20 years | -- | 3 | 6 | 9 | 4 | 2 | 24 |
| 21-40 years | 30 | 27 | 51 | 87 | 45 | 40 | 280 |
| 41-60 years | 18 | 2 | 34 | 56 | 12 | 19 | 141 |
| 61-80 years | 30 | -- | 81 | 52 | -- | -- | 163 |
| 81-100 years | 8 | 16 | 32 | 85 | 17 | 14 | 172 |
| 101-120 years | 9 | -- | 48 | 63 | 40 | -- | 160 |
| 121-140 years | 9 | -- | -- | 39 | -- | 5 | 53 |
| 141-160 years | 17 | -- | 6 | 52 | 31 | -- | 106 |
| 161-180 years | -- | -- | -- | 36 | 13 | -- | 49 |
| 181-200 years | 9 | 7 | 5 | 56 | -- | -- | 77 |
| 201-250 years | 16 | 7 | 15 | 92 | -- | -- | 130 |
| 251-300 years | 13 | 6 | -- | 77 | 20 | -- | 116 |
| 301-350 years | 4 | 2 | 11 | 47 | 21 | 5 | 90 |
| 351 years or older | -- | -- | -- | 81 | 33 | -- | 114 |
| Uneven aged | -- | 23 | 43 | 81 | 19 | -- | 166 |
| All classes | 163 | 93 | 337 | 927 | 255 | 87 | 1,862 |
| **TYPE-SITE 4** | | | | | | | |
| Burns and old cutovers | 4 | -- | 5 | 12 | 5 | 5 | 31 |
| Recent cutovers | 4 | -- | -- | -- | -- | -- | 4 |
| 1-20 years | -- | -- | -- | 10 | -- | -- | 10 |
| 21-40 years | -- | -- | 8 | 71 | 2 | 1 | 82 |
| 41-60 years | 3 | 1 | -- | 60 | 3 | -- | 67 |
| 61-80 years | -- | 8 | 2 | 18 | 3 | 1 | 32 |
| 81-100 years | -- | -- | -- | 24 | -- | -- | 24 |
| 101-120 years | -- | -- | -- | 47 | -- | -- | 47 |
| 121-140 years | -- | -- | -- | 14 | 1 | -- | 15 |
| 141-160 years | 1 | -- | -- | 29 | -- | 3 | 33 |
| 161-180 years | -- | -- | -- | 23 | 2 | -- | 25 |
| 181-200 years | 11 | -- | -- | 71 | -- | -- | 82 |
| 201-250 years | 10 | 1 | 10 | 92 | 3 | 2 | 118 |
| 251-300 years | 10 | -- | -- | 78 | 3 | -- | 91 |
| 301-350 years | 1 | 1 | -- | 36 | -- | -- | 38 |
| 351 years or older | -- | -- | -- | 4 | -- | -- | 4 |
| Uneven aged | 10 | 1 | 1 | 75 | 2 | -- | 89 |
| All classes | 54 | 12 | 26 | 664 | 24 | 12 | 792 |
| **TYPE-SITE 5** | | | | | | | |
| 1-20 years | 27 | 30 | 80 | 15 | 11 | 49 | 212 |
| 21-40 years | 16 | 6 | 107 | 17 | 3 | 13 | 162 |
| 41-60 years | -- | 29 | 153 | 9 | 2 | 6 | 199 |
| 61-80 years | -- | -- | 23 | 13 | 5 | 2 | 43 |
| 81-100 years | -- | -- | -- | 4 | 2 | 1 | 7 |
| 101-120 years | -- | -- | 15 | -- | -- | 1 | 16 |
| 121 years or older | 3 | -- | -- | 1 | -- | -- | 4 |
| Uneven aged | -- | -- | 33 | 1 | -- | 2 | 36 |
| All classes | 46 | 65 | 411 | 60 | 23 | 74 | 679 |

Table 28. — Area of commercial forest land, by type-site, ownership, and stand-age classes, Southwest Oregon district, decade of 1950's

(In thousand acres)

ALL TYPE-SITE CLASSES

| Land class or stand age | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Federal Other | Other | |
| Burns and old cutovers | 37 | 5 | 57 | 36 | 68 | 3 | 206 |
| Recent cutovers | 57 | 60 | 102 | 187 | 86 | 3 | 495 |
| 1-20 years | 99 | 72 | 185 | 19 | 102 | 10 | 487 |
| 21-40 years | 53 | 113 | 201 | 72 | 191 | 18 | 648 |
| 41-60 years | 46 | -- | 138 | 113 | 51 | 1 | 349 |
| 61-80 years | 67 | 59 | 142 | 101 | 132 | 57 | 558 |
| 81-100 years | 48 | 4 | 234 | 114 | 99 | 28 | 527 |
| 101-120 years | -- | 4 | 84 | 72 | 35 | -- | 195 |
| 121-140 years | -- | 50 | -- | 69 | 61 | -- | 180 |
| 141-160 years | -- | -- | 46 | 81 | -- | -- | 127 |
| 161-180 years | -- | -- | 23 | 65 | 71 | 1 | 160 |
| 181-200 years | 128 | 101 | 54 | 122 | 71 | 29 | 505 |
| 201-250 years | 89 | -- | 111 | 215 | 98 | 1 | 514 |
| 251-300 years | 130 | 67 | 46 | 153 | 165 | -- | 561 |
| 301-350 years | 94 | -- | 23 | 36 | 99 | -- | 252 |
| 351 years or older | -- | -- | -- | 27 | 132 | -- | 159 |
| Uneven aged | 17 | -- | 50 | 705 | 77 | 3 | 852 |
| All classes | 865 | 535 | 1,496 | 2,187 | 1,538 | 154 | 6,775 |

TYPE-SITE 1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Burns and old cutovers | 8 | -- | 17 | 1 | -- | -- | 26 |
| Recent cutovers | 38 | 15 | 26 | 8 | 22 | 1 | 110 |
| 1-20 years | 60 | 19 | 42 | 2 | 42 | 7 | 172 |
| 21-40 years | 11 | 29 | 51 | 5 | 7 | 1 | 104 |
| 41-60 years | 43 | -- | 61 | 10 | -- | -- | 114 |
| 61-80 years | 67 | 51 | 49 | 8 | 132 | 57 | 364 |
| 81-100 years | 15 | -- | 116 | 15 | 33 | -- | 179 |
| 101-120 years | -- | -- | 23 | 4 | 33 | -- | 60 |
| 121-140 years | -- | -- | -- | 2 | -- | -- | 2 |
| 141-160 years | -- | -- | -- | 6 | -- | -- | 6 |
| 161-180 years | -- | -- | -- | 5 | 33 | -- | 38 |
| 181-200 years | 87 | -- | 27 | 10 | 66 | -- | 190 |
| 201-250 years | 43 | -- | 24 | 28 | -- | -- | 95 |
| 251-300 years | 130 | 8 | 23 | 24 | 99 | -- | 284 |
| 301-350 years | 50 | -- | -- | 2 | 66 | -- | 118 |
| 351 years or older | -- | -- | -- | 3 | 66 | -- | 69 |
| Uneven aged | 15 | -- | 46 | 68 | 4 | 1 | 134 |
| All classes | 567 | 122 | 505 | 201 | 603 | 67 | 2,065 |

TYPE-SITE 2

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Burns and old cutovers | 25 | 5 | 11 | 5 | 15 | -- | 61 |
| Recent cutovers | 18 | 40 | 50 | 23 | 43 | 1 | 175 |
| 1-20 years | 28 | 44 | 94 | 5 | 32 | 1 | 204 |
| 21-40 years | 28 | 24 | 64 | 9 | 122 | 12 | 259 |
| 41-60 years | -- | -- | 52 | 20 | 33 | -- | 105 |
| 61-80 years | -- | 8 | 69 | 15 | -- | -- | 92 |
| 81-100 years | 33 | -- | 54 | 24 | 33 | 28 | 172 |
| 101-120 years | -- | -- | -- | 15 | -- | -- | 15 |
| 121-140 years | -- | -- | -- | 13 | 33 | -- | 46 |
| 141-160 years | -- | -- | 23 | 14 | -- | -- | 37 |
| 161-180 years | -- | -- | -- | 12 | 38 | 1 | 51 |
| 181-200 years | 41 | -- | 24 | 26 | -- | 28 | 119 |
| 201-250 years | -- | -- | 41 | 55 | 65 | -- | 161 |
| 251-300 years | -- | 59 | 23 | 36 | 66 | -- | 184 |
| 301-350 years | 44 | -- | -- | 7 | -- | -- | 51 |
| 351 years or older | -- | -- | -- | 15 | 66 | -- | 81 |
| Uneven aged | -- | -- | 4 | 183 | 38 | -- | 225 |
| All classes | 217 | 180 | 509 | 477 | 584 | 71 | 2,038 |

Table 28. — Area of commercial forest land, by type-site, ownership, and stand-age classes Southwest Oregon district, decade of 1950's—Continued

(In thousand acres)

| Land class or stand age | Private holdings | | | Public holdings | | | All holdings |
|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | National Forest | Other Federal | Other | |
| **TYPE-SITE 3** | | | | | | | |
| Burns and old cutovers | 4 | -- | 27 | 21 | 53 | 3 | 108 |
| Recent cutovers | -- | 5 | 26 | 110 | 21 | -- | 162 |
| 1-20 years | 3 | -- | 15 | 9 | 22 | 1 | 50 |
| 21-40 years | 8 | -- | 30 | 29 | 50 | 2 | 119 |
| 41-60 years | 3 | -- | 25 | 43 | 18 | 1 | 90 |
| 61-80 years | -- | -- | 24 | 40 | -- | -- | 64 |
| 81-100 years | -- | -- | 64 | 45 | 33 | -- | 142 |
| 101-120 years | -- | -- | 61 | 33 | -- | -- | 94 |
| 121-140 years | -- | 50 | -- | 33 | -- | -- | 83 |
| 141-160 years | -- | -- | 23 | 40 | -- | -- | 63 |
| 161-180 years | -- | -- | 23 | 33 | -- | -- | 56 |
| 181-200 years | -- | 101 | 3 | 57 | 5 | 1 | 167 |
| 201-250 years | 44 | -- | 46 | 83 | 33 | -- | 206 |
| 251-300 years | -- | -- | -- | 76 | -- | -- | 76 |
| 301-350 years | -- | -- | 23 | 23 | 33 | -- | 79 |
| 351 years or older | -- | -- | -- | 7 | -- | -- | 7 |
| Uneven aged | -- | -- | -- | 254 | 33 | -- | 287 |
| All classes | 62 | 156 | 390 | 936 | 301 | 8 | 1,853 |
| **TYPE-SITE 4** | | | | | | | |
| Burns and old cutovers | -- | -- | 2 | 9 | -- | -- | 11 |
| Recent cutovers | 1 | -- | -- | 46 | -- | 1 | 48 |
| 1-20 years | -- | -- | -- | -- | -- | -- | -- |
| 21-40 years | -- | 16 | -- | 10 | -- | -- | 26 |
| 41-60 years | -- | -- | -- | 25 | -- | -- | 25 |
| 61-80 years | -- | -- | -- | 27 | -- | -- | 27 |
| 81-100 years | -- | 4 | -- | 27 | -- | -- | 31 |
| 101-120 years | -- | 4 | -- | 16 | 2 | -- | 22 |
| 121-140 years | -- | -- | -- | 20 | 28 | -- | 48 |
| 141-160 years | -- | -- | -- | 20 | -- | -- | 20 |
| 161-180 years | -- | -- | -- | 14 | -- | -- | 14 |
| 181-200 years | -- | -- | -- | 28 | -- | -- | 28 |
| 201-250 years | 2 | -- | -- | 48 | -- | 1 | 51 |
| 251-300 years | -- | -- | -- | 17 | -- | -- | 17 |
| 301-350 years | -- | -- | -- | 4 | -- | -- | 4 |
| 351 years or older | -- | -- | -- | 2 | -- | -- | 2 |
| Uneven aged | -- | -- | -- | 189 | -- | -- | 189 |
| All classes | 3 | 24 | 2 | 502 | 30 | 2 | 563 |
| **TYPE-SITE 5** | | | | | | | |
| 1-20 years | 8 | 9 | 34 | 3 | 6 | 1 | 61 |
| 21-40 years | 6 | 44 | 56 | 19 | 12 | 3 | 140 |
| 41-60 years | -- | -- | -- | 15 | -- | -- | 15 |
| 61-80 years | -- | -- | -- | 11 | -- | -- | 11 |
| 81-100 years | -- | -- | -- | 3 | -- | -- | 3 |
| 101-120 years | -- | -- | -- | 4 | -- | -- | 4 |
| 121 years or older | -- | -- | -- | 5 | -- | -- | 5 |
| Uneven aged | 2 | -- | -- | 11 | 2 | 2 | 17 |
| | 16 | 53 | 90 | 71 | 20 | 6 | 256 |

Table 29. — Quantity of live sawtimber in the Douglas-fir subregion, by district, ownership class, and forest type-site class, decade of 1950's

(In million board feet, net Scribner scale)

| Type-site class | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DOUGLAS-FIR SUBREGION** | | | | | | | | | |
| 1 | 92,180 | 10,936 | 30,978 | 134,094 | 78,391 | 31,972 | 16,840 | 127,203 | 261,297 |
| 2 | 42,826 | 8,225 | 22,581 | 73,632 | 78,379 | 21,506 | 9,135 | 109,020 | 182,652 |
| 3 | 17,802 | 5,477 | 10,965 | 34,244 | 75,009 | 7,562 | 11,448 | 94,019 | 128,263 |
| 4 | 5,024 | 1,125 | 438 | 6,587 | 52,508 | 844 | 4,269 | 57,621 | 64,208 |
| 5 | 1,607 | 1,209 | 4.831 | 7,647 | 1,146 | 745 | 888 | 2,779 | 10,426 |
| All | 159,439 | 26,972 | 69,793 | 256,204 | 285,433 | 62,629 | 42,580 | 390,642 | 646,846 |
| **PUGET SOUND DISTRICT** | | | | | | | | | |
| 1 | 27,885 | 1,672 | 4,022 | 33,579 | 10,081 | 596 | 6,180 | 16,857 | 50,436 |
| 2 | 10,845 | 900 | 5,111 | 16,856 | 16,192 | 666 | 3,881 | 20,739 | 37,595 |
| 3 | 10,844 | 1,380 | 1,669 | 13,933 | 21,691 | 377 | 10,407 | 32,475 | 46,408 |
| 4 | 1,994 | 325 | 245 | 2,564 | 19,944 | 67 | 3,924 | 23,935 | 26,499 |
| 5 | 1,296 | 446 | 1,712 | 3,454 | 66 | 334 | 721 | 1,121 | 4,575 |
| All | 52,904 | 4,723 | 12,759 | 70,386 | 67,974 | 2,040 | 25,113 | 95,127 | 165,513 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | | | |
| 1 | 36,186 | 7,820 | 15,072 | 59,078 | 58,857 | 8,797 | 8,009 | 75,663 | 134,741 |
| 2 | 25,954 | 4,429 | 12,651 | 43,034 | 43,379 | 10,249 | 3,855 | 57,483 | 100,517 |
| 3 | 5,883 | 2,488 | 4,915 | 13,286 | 31,727 | 5,644 | 1,021 | 38,392 | 51,678 |
| 4 | 2,982 | 241 | 193 | 3,416 | 20,868 | 317 | 304 | 21,489 | 24,905 |
| 5 | 271 | 464 | 3,116 | 3,851 | 807 | 393 | 134 | 1,334 | 5,185 |
| All | 71,276 | 15,442 | 35,947 | 122,665 | 155,638 | 25,400 | 13,323 | 194,361 | 317,026 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | | | |
| 1 | 28,109 | 1,444 | 11,884 | 41,437 | 9,453 | 22,579 | 2,651 | 34,683 | 76,120 |
| 2 | 6,027 | 2,896 | 4,819 | 13,742 | 18,808 | 10,591 | 1,399 | 30,798 | 44,540 |
| 3 | 1,035 | 1,609 | 4,381 | 7,025 | 21,591 | 1,541 | 20 | 23,152 | 30,177 |
| 4 | 48 | 559 | -- | 607 | 11,696 | 460 | 41 | 12,197 | 12,804 |
| 5 | 40 | 299 | 3 | 342 | 273 | 18 | 33 | 324 | 666 |
| All | 35,259 | 6,807 | 21,087 | 63,153 | 61,821 | 35,189 | 4,144 | 101,154 | 164,307 |

Table 30. — Quantity of live sawtimber per acre of commercial forest land in the Douglas-fir subregion, by district, ownership class, and forest type-site class, decade of 1950's

(In board feet, net Scribner scale)

| Type-site class | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DOUGLAS-FIR SUBREGION** | | | | | | | | | |
| 1 | 33,168 | 17,706 | 15,024 | 24,565 | 50,019 | 36,868 | 16,028 | 39,186 | 30,017 |
| 2 | 25,078 | 15,553 | 11,654 | 17,640 | 42,402 | 22,530 | 14,060 | 31,575 | 23,948 |
| 3 | 30,778 | 14,431 | 9,344 | 16,066 | 30,248 | 12,371 | 29,510 | 27,025 | 22,861 |
| 4 | 54,211 | 23,311 | 10,816 | 36,307 | 31,127 | 12,315 | 37,496 | 30,824 | 31,309 |
| 5 | 5,538 | 7,161 | 5,326 | 5,598 | 7,656 | 10,547 | 4,747 | 6,821 | 5,879 |
| All | 29,264 | 15,474 | 11,403 | 19,246 | 38,093 | 24,348 | 17,821 | 31,365 | 25,104 |
| **PUGET SOUND DISTRICT** | | | | | | | | | |
| 1 | 29,377 | 18,084 | 8,544 | 22,203 | 58,059 | 64,244 | 19,448 | 33,668 | 25,054 |
| 2 | 18,818 | 11,833 | 8,818 | 13,683 | 38,923 | 14,631 | 15,785 | 29,317 | 19,386 |
| 3 | 30,790 | 10,554 | 3,732 | 14,959 | 35,189 | 6,953 | 35,528 | 33,702 | 24,490 |
| 4 | 55,549 | 26,029 | 19,240 | 41,946 | 38,267 | 4,562 | 39,656 | 37,711 | 38,083 |
| 5 | 5,704 | 8,738 | 4,216 | 5,047 | 3,570 | 11,900 | 6,707 | 6,619 | 5,456 |
| All | 24,697 | 13,018 | 6,658 | 15,920 | 38,935 | 13,446 | 23,626 | 32,132 | 22,422 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | | | |
| 1 | 28,642 | 19,430 | 13,880 | 21,469 | 61,671 | 34,454 | 12,028 | 40,342 | 29,119 |
| 2 | 28,380 | 16,234 | 14,902 | 21,133 | 45,390 | 31,553 | 11,584 | 35,632 | 27,542 |
| 3 | 36,082 | 27,065 | 14,602 | 22,458 | 34,212 | 22,063 | 11,641 | 33,103 | 27,747 |
| 4 | 55,456 | 19,610 | 7,362 | 37,040 | 31,469 | 13,409 | 24,617 | 30,735 | 31,470 |
| 5 | 5,832 | 7,121 | 7,586 | 7,372 | 13,413 | 17,281 | 1,818 | 8,506 | 7,634 |
| All | 29,197 | 18,282 | 13,272 | 20,464 | 43,710 | 28,786 | 11,362 | 34,610 | 27,306 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | | | |
| 1 | 49,608 | 11,764 | 23,518 | 28,831 | 47,212 | 37,469 | 39,549 | 39,872 | 36,870 |
| 2 | 27,786 | 16,093 | 9,466 | 15,168 | 39,450 | 18,130 | 19,682 | 27,206 | 21,855 |
| 3 | 16,731 | 10,263 | 11,240 | 11,546 | 23,066 | 5,116 | 2,714 | 18,603 | 16,286 |
| 4 | 15,928 | 23,803 | 23 | 21,612 | 23,272 | 15,178 | 15,929 | 22,778 | 22,720 |
| 5 | 2,439 | 5,684 | 26 | 2,148 | 3,848 | 874 | 5,819 | 3,357 | 2,604 |
| All | 40,763 | 12,709 | 14,097 | 21,804 | 28,273 | 22,878 | 26,955 | 26,082 | 24,253 |

Table 31. — Quantity of all growing stock in the Douglas-fir subregion, by district, ownership class, and forest type-site class, decade of 1950's

(In million cubic feet)

| Type-site class | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DOUGLAS-FIR SUBREGION** | | | | | | | | | |
| 1 | 15,810 | 2,176 | 6,643 | 24,629 | 13,479 | 5,213 | 3,455 | 22,147 | 46,776 |
| 2 | 7,663 | 1,430 | 5,002 | 14,095 | 13,792 | 3,744 | 1,767 | 19,303 | 33,398 |
| 3 | 3,334 | 1,130 | 2,546 | 7,010 | 14,851 | 1,454 | 2,244 | 18,549 | 25,559 |
| 4 | 978 | 247 | 111 | 1,336 | 11,062 | 188 | 819 | 12,069 | 13,405 |
| 5 | 536 | 317 | 1,263 | 2,116 | 311 | 168 | 246 | 725 | 2,841 |
| All | 28,321 | 5,300 | 15,565 | 49,186 | 53,495 | 10,767 | 8,531 | 72,793 | 121,979 |
| **PUGET SOUND DISTRICT** | | | | | | | | | |
| 1 | 4,935 | 327 | 1,222 | 6,484 | 1,599 | 101 | 1,292 | 2,992 | 9,476 |
| 2 | 2,211 | 209 | 1,218 | 3,638 | 2,761 | 137 | 798 | 3,696 | 7,334 |
| 3 | 1,983 | 336 | 543 | 2,862 | 4,159 | 79 | 1,986 | 6,224 | 9,086 |
| 4 | 398 | 64 | 50 | 512 | 3,916 | 14 | 750 | 4,680 | 5,192 |
| 5 | 460 | 110 | 612 | 1,182 | 26 | 85 | 184 | 295 | 1,477 |
| All | 9,987 | 1,046 | 3,645 | 14,678 | 12,461 | 416 | 5,010 | 17,887 | 32,565 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | | | |
| 1 | 6,383 | 1,490 | 3,256 | 11,129 | 10,171 | 1,509 | 1,656 | 13,336 | 24,465 |
| 2 | 4,503 | 776 | 2,667 | 7,946 | 7,426 | 1,775 | 728 | 9,929 | 17,875 |
| 3 | 1,148 | 476 | 1,085 | 2,709 | 6,187 | 1,077 | 255 | 7,519 | 10,228 |
| 4 | 571 | 57 | 61 | 689 | 4,337 | 72 | 62 | 4,471 | 5,160 |
| 5 | 65 | 94 | 650 | 809 | 175 | 76 | 52 | 303 | 1,112 |
| All | 12,670 | 2,893 | 7,719 | 23,282 | 28,296 | 4,509 | 2,753 | 35,558 | 58,840 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | | | |
| 1 | 4,492 | 359 | 2,165 | 7,016 | 1,709 | 3,603 | 506 | 5,818 | 12,834 |
| 2 | 949 | 445 | 1,118 | 2,512 | 3,606 | 1,832 | 240 | 5,678 | 8,190 |
| 3 | 202 | 317 | 918 | 1,437 | 4,506 | 298 | 4 | 4,808 | 6,245 |
| 4 | 9 | 126 | -- | 135 | 2,808 | 103 | 8 | 2,919 | 3,054 |
| 5 | 11 | 114 | 1 | 126 | 110 | 6 | 9 | 125 | 251 |
| All | 5,664 | 1,361 | 4,201 | 11,226 | 12,739 | 5,842 | 767 | 19,348 | 30,574 |

Table 32. — Quantity of all growing stock per acre of commercial forest land in the Douglas-fir subregion, by district, ownership class, and forest type-site class, decade of 1950's

(In cubic feet)

| Type-site class | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DOUGLAS-FIR SUBREGION** | | | | | | | | | |
| 1 | 5,688 | 3,523 | 3,222 | 4,512 | 10,148 | 6,011 | 3,288 | 6,822 | 5,373 |
| 2 | 4,489 | 2,704 | 2,582 | 3,377 | 7,462 | 3,922 | 2,720 | 5,591 | 4,379 |
| 3 | 5,764 | 2,978 | 2,169 | 3,289 | 5,989 | 2,379 | 5,784 | 5,332 | 4,556 |
| 4 | 10,555 | 5,123 | 2,726 | 7,374 | 6,557 | 2,748 | 7,198 | 6,457 | 6,537 |
| 5 | 1,846 | 1,878 | 1,393 | 1,549 | 2,079 | 2,378 | 1,314 | 1,780 | 1,602 |
| All | 5,199 | 3,041 | 2,543 | 3,695 | 7,139 | 4,186 | 3,571 | 5,845 | 4,734 |
| **PUGET SOUND DISTRICT** | | | | | | | | | |
| 1 | 5,199 | 3,536 | 2,597 | 4,288 | 9,210 | 10,865 | 4,067 | 5,977 | 4,708 |
| 2 | 3,836 | 2,753 | 2,101 | 2,953 | 6,636 | 3,012 | 3,246 | 5,224 | 3,782 |
| 3 | 5,611 | 2,571 | 1,214 | 3,073 | 6,747 | 1,452 | 6,779 | 6,458 | 4,795 |
| 4 | 11,093 | 5,122 | 3,866 | 8,366 | 7,515 | 965 | 7,578 | 7,375 | 7,462 |
| 5 | 2,023 | 2,144 | 1,508 | 1,726 | 1,408 | 3,021 | 1,717 | 1,917 | 1,761 |
| All | 4,662 | 2,883 | 1,902 | 3,320 | 7,138 | 2,740 | 4,714 | 5,029 | 4,412 |
| **COLUMBIA RIVER DISTRICT** | | | | | | | | | |
| 1 | 5,052 | 3,702 | 2,999 | 4,044 | 10,657 | 5,912 | 2,487 | 7,110 | 5,287 |
| 2 | 4,924 | 2,843 | 3,141 | 3,902 | 7,770 | 5,465 | 2,190 | 6,155 | 4,898 |
| 3 | 7,045 | 5,181 | 3,223 | 4,580 | 6,671 | 4,212 | 2,904 | 5,916 | 5,492 |
| 4 | 10,613 | 4,679 | 2,335 | 7,475 | 6,540 | 3,004 | 4,996 | 6,393 | 6,519 |
| 5 | 1,395 | 1,444 | 1,581 | 1,548 | 2,911 | 3,371 | 707 | 1,938 | 1,638 |
| All | 5,190 | 3,425 | 2,850 | 3,884 | 7,947 | 5,111 | 2,348 | 6,332 | 5,068 |
| **SOUTHWEST OREGON DISTRICT** | | | | | | | | | |
| 1 | 7,928 | 2,926 | 4,284 | 5,873 | 8,534 | 5,978 | 7,556 | 6,688 | 6,216 |
| 2 | 4,377 | 2,473 | 2,195 | 2,773 | 7,564 | 3,136 | 3,380 | 5,019 | 4,019 |
| 3 | 3,269 | 2,026 | 2,354 | 2,362 | 4,813 | 989 | 518 | 3,863 | 3,370 |
| 4 | 3,082 | 5,355 | 10 | 4,809 | 5,587 | 3,402 | 3,084 | 5,452 | 5,420 |
| 5 | 680 | 2,156 | 14 | 791 | 1,551 | 321 | 1,603 | 1,302 | 984 |
| All | 6,548 | 2,541 | 2,809 | 3,876 | 5,826 | 3,798 | 4,993 | 4,989 | 4,513 |

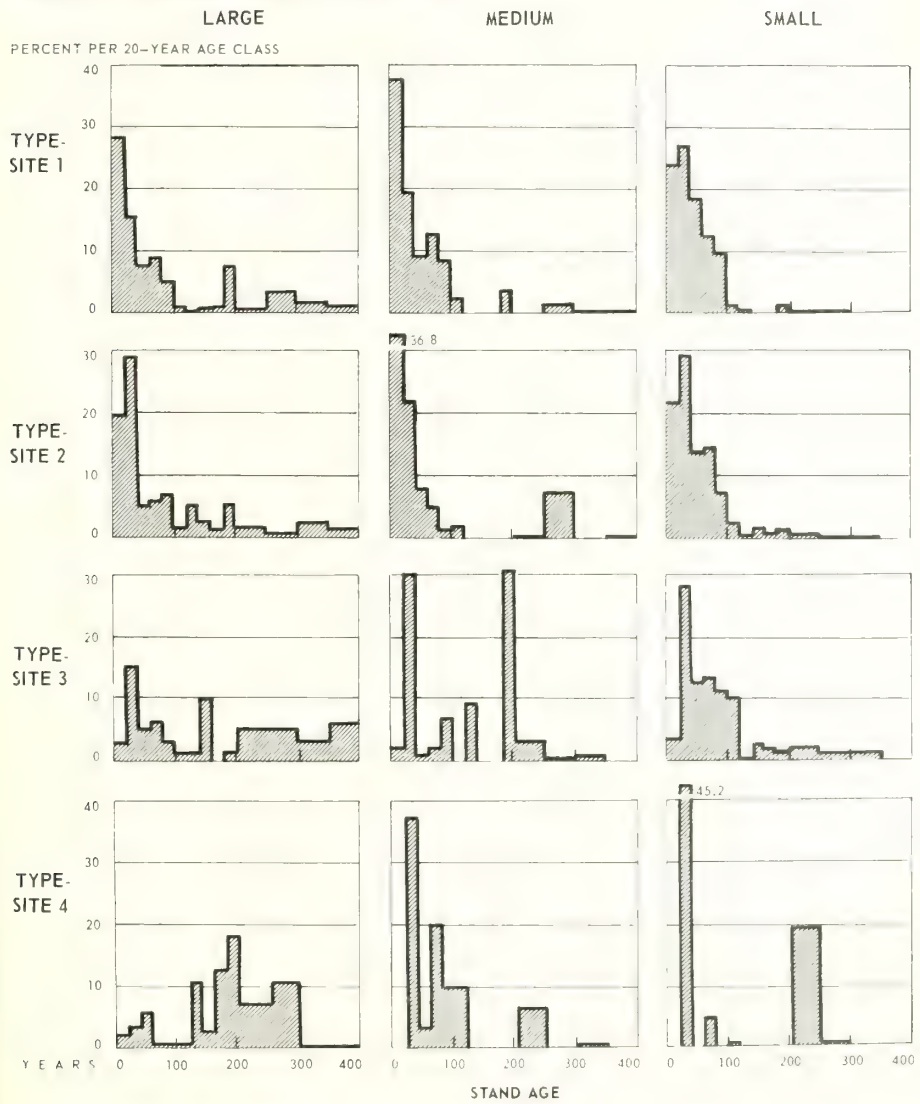


Figure 15.—Age-class distribution of even-aged coniferous commercial forest area in the Douglas-fir subregion, by type-site and ownership classes, decade of 1950's.

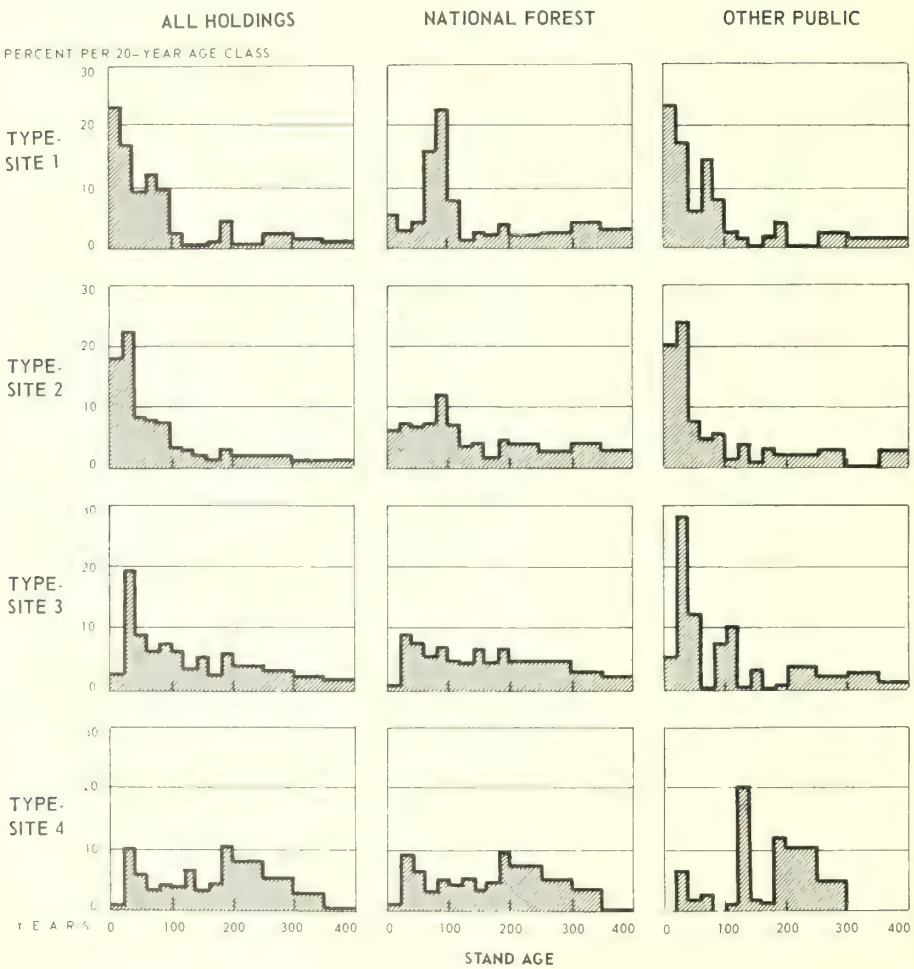


Figure 15.—Age-class distribution of even-aged coniferous commercial forest area in the Douglas-fir subregion, by type-site and ownership classes, decade of 1950's—Continued.

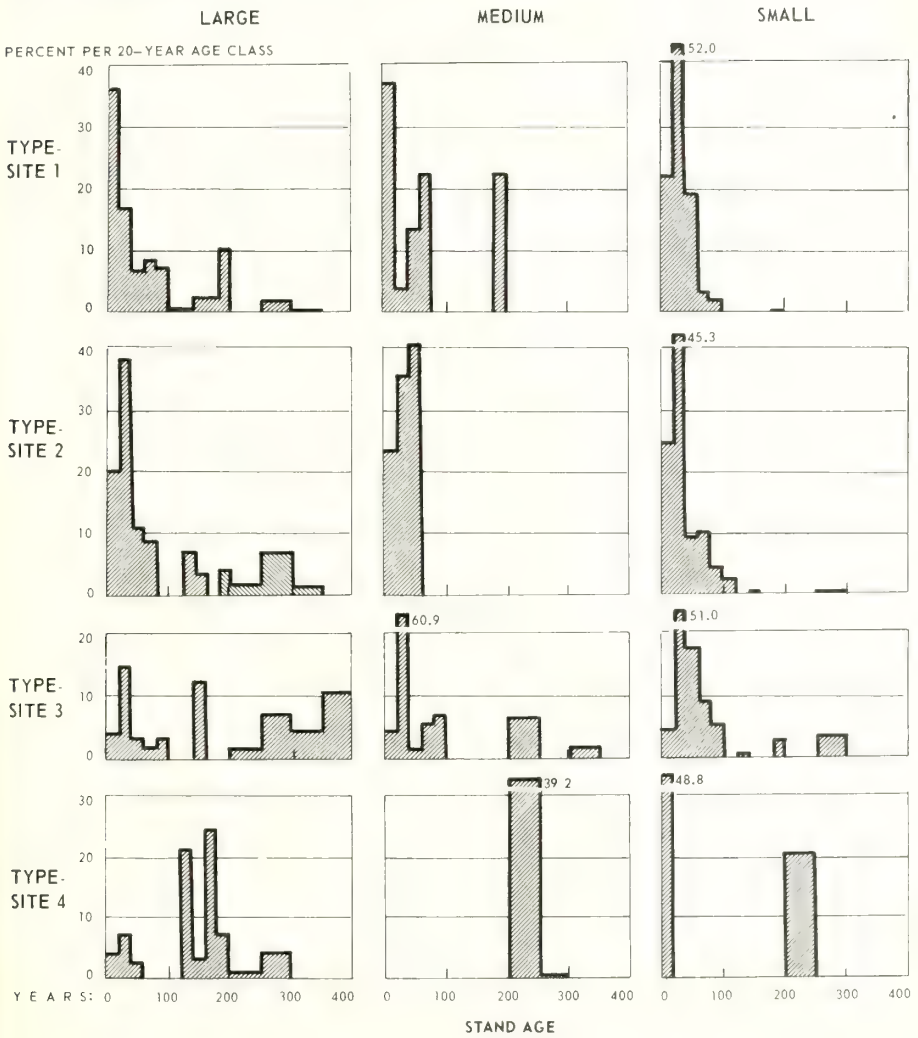


Figure 16.—Age-class distribution of even-aged coniferous commercial forest area in the Puget Sound district, by type-site and ownership classes, decade of 1950's.

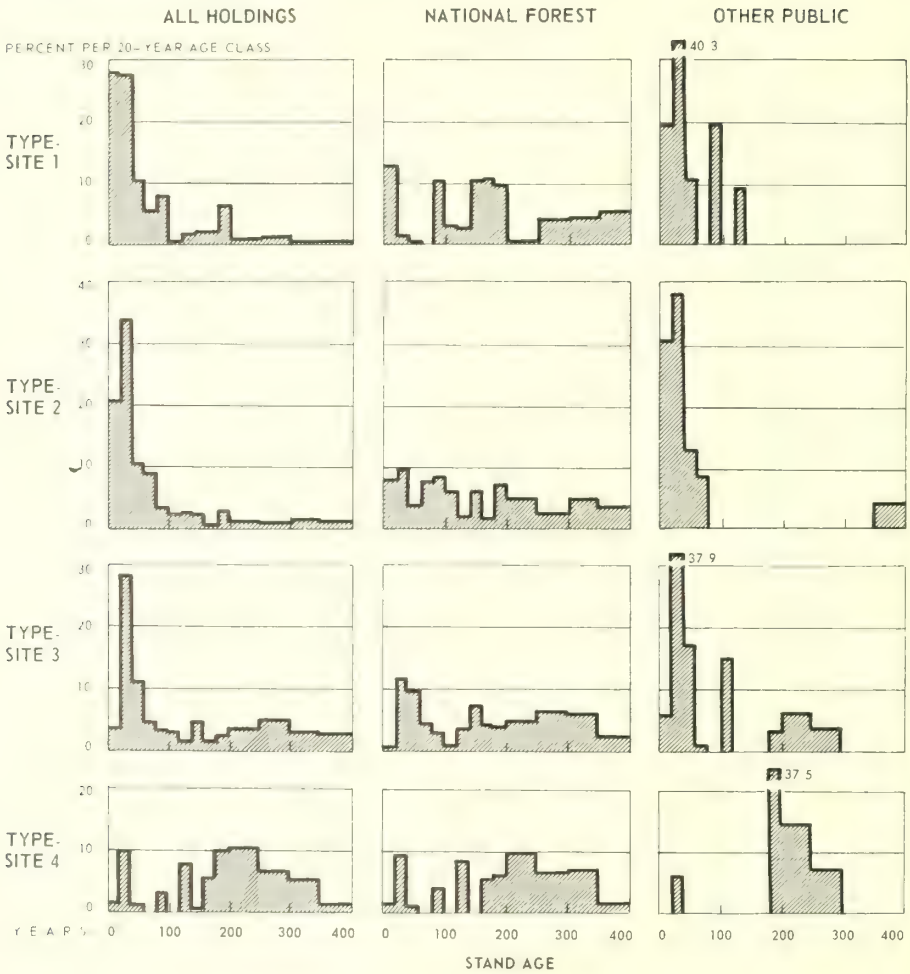


Figure 16.—Age-class distribution of even-aged coniferous commercial forest area in the Puget Sound district, by type-site and ownership classes, decade of 1950's—Continued.

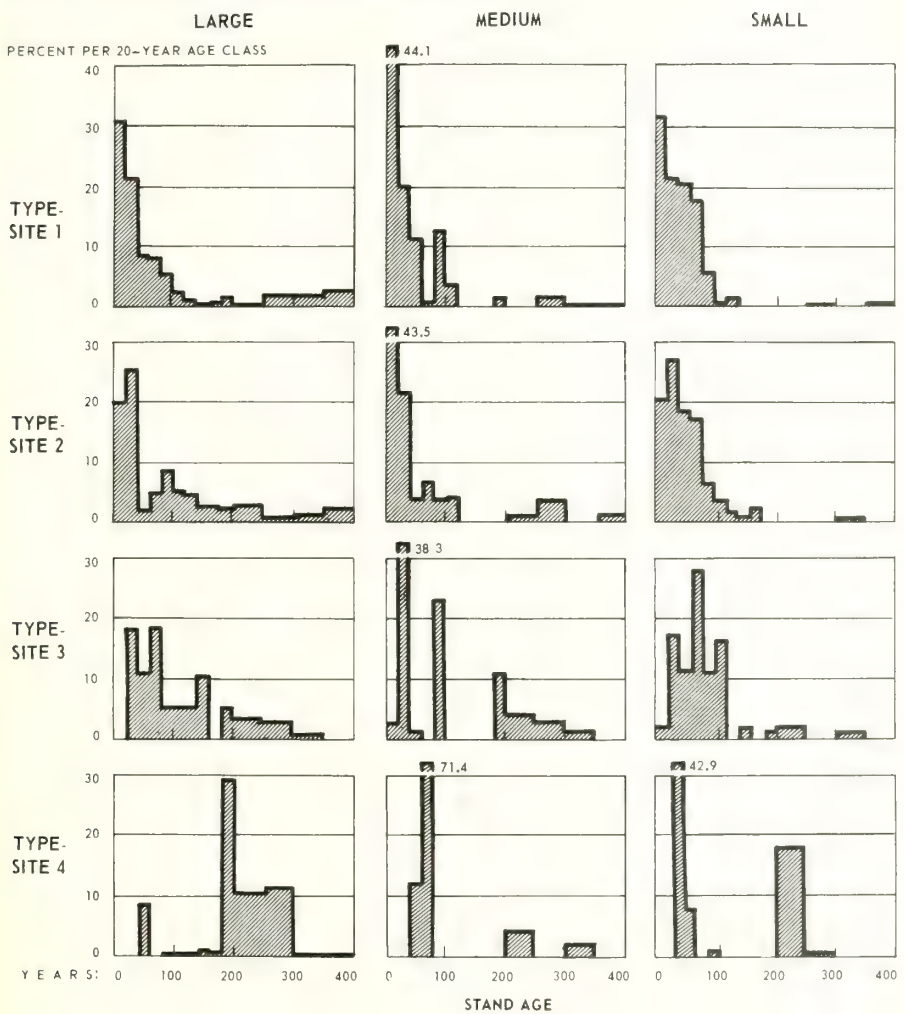


Figure 17.—Age-class distribution of even-aged coniferous commercial forest area in the Columbia River district, by type-site and ownership classes decade of 1950's.

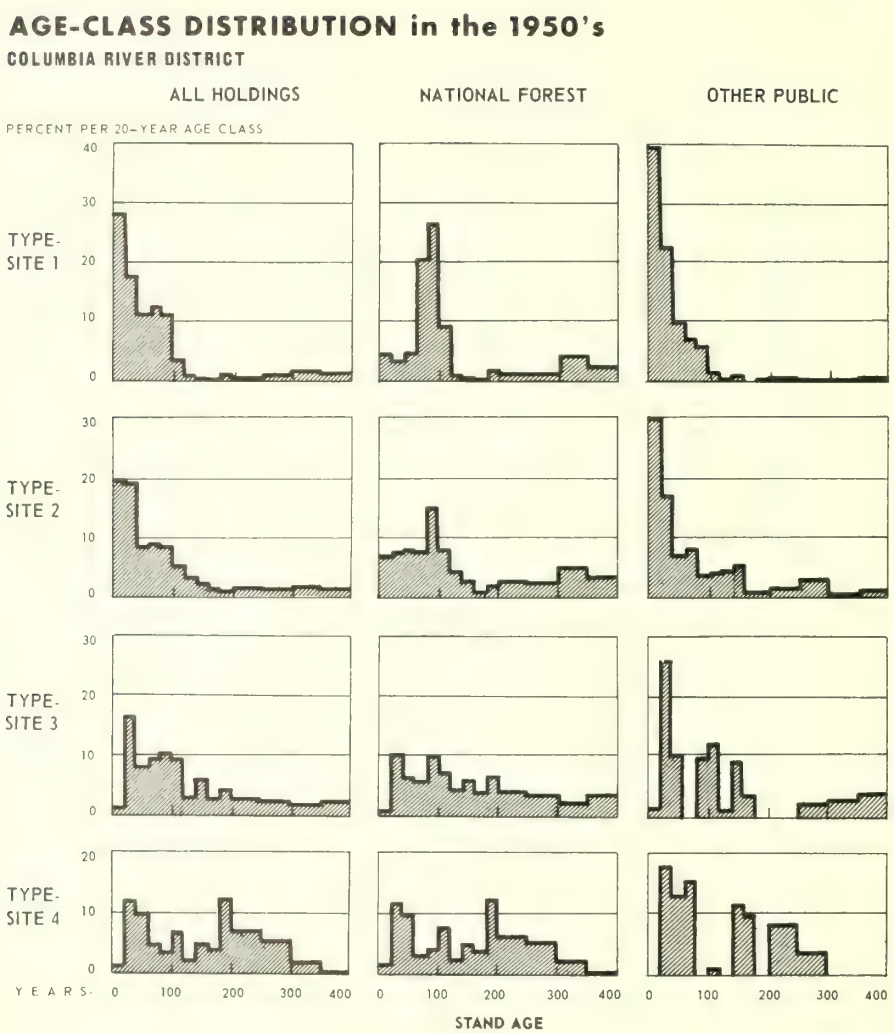


Figure 17.—Age-class distribution of even-aged coniferous commercial forest area in the Columbia River district, by type-site and ownership classes, decade of 1950's—Continued.

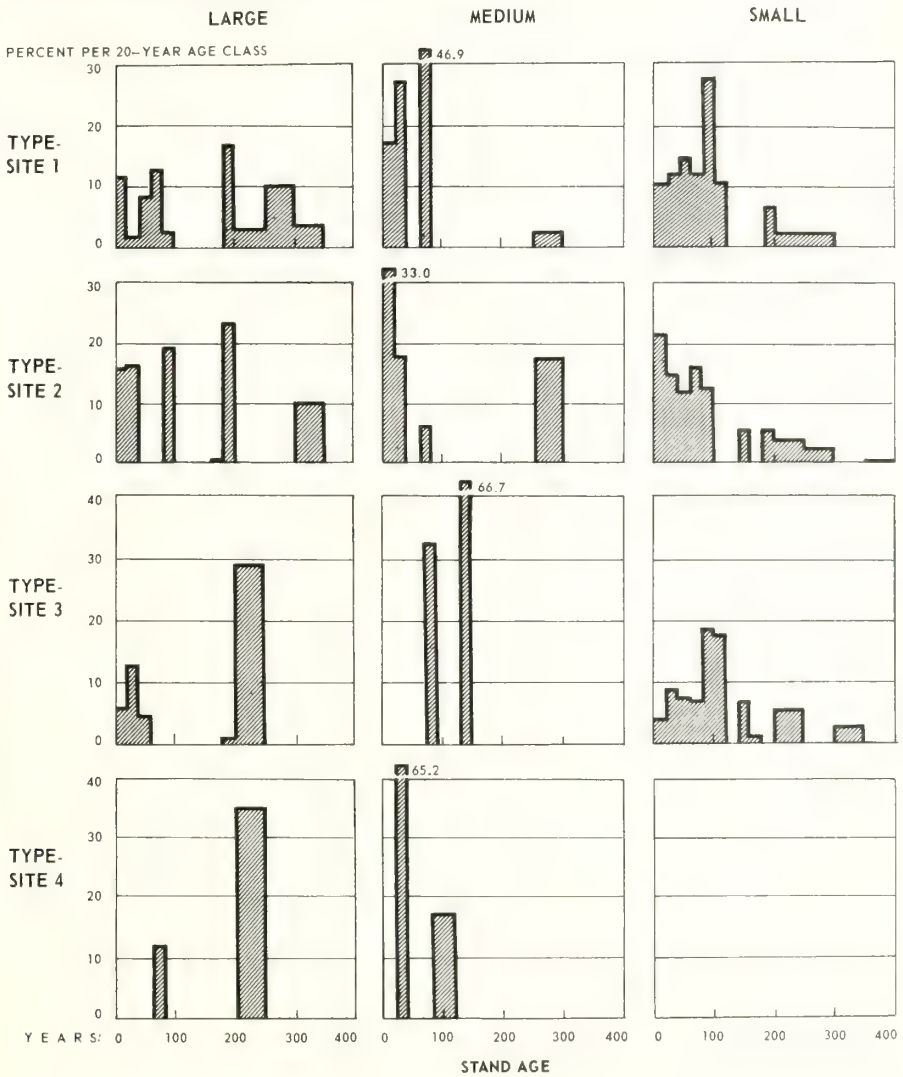


Figure 18.—Age-class distribution of even-aged coniferous commercial forest area in the Southwest Oregon district, by type-site and ownership classes, decade of 1950's.

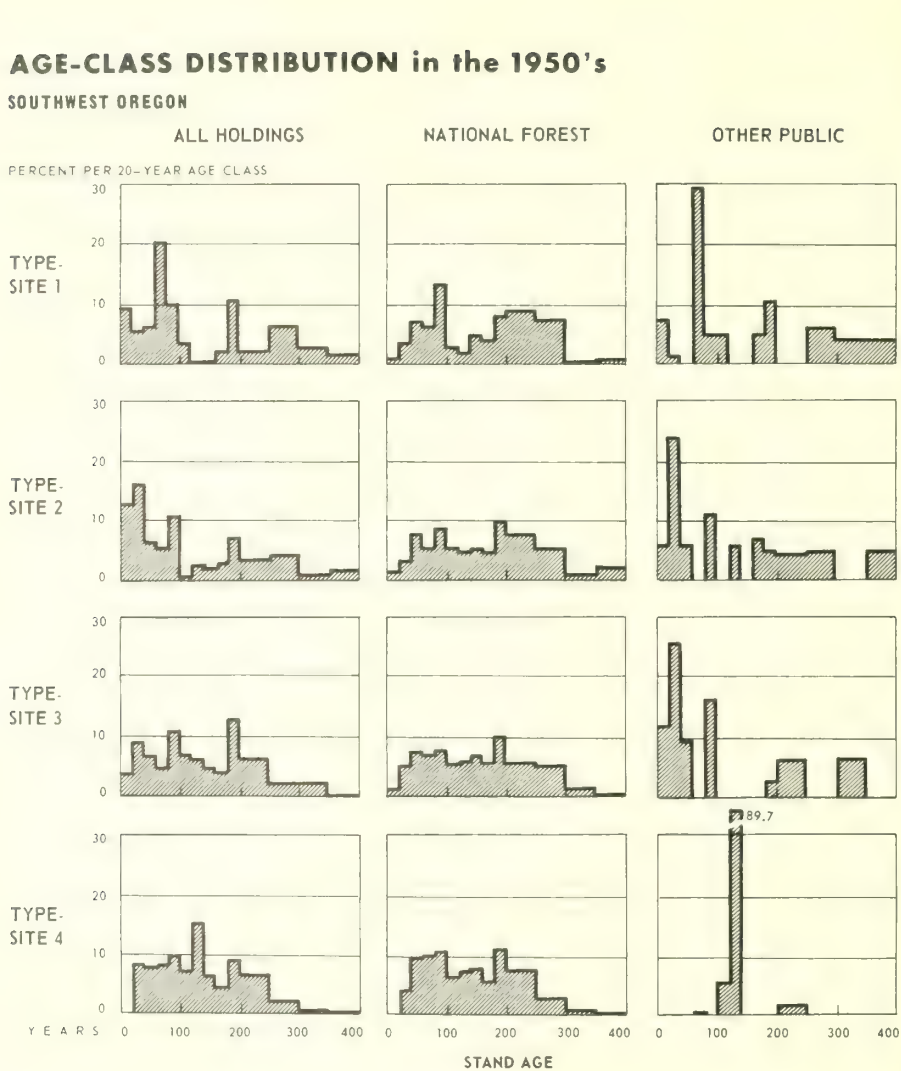


Figure 18.—Age-class distribution of even-aged coniferous commercial forest area in the Southwest Oregon district, by type-site and ownership classes, decade of 1950's—Continued.

# Appendix B

## Timber Growth

Tables 33-40 show the estimates used in this report of prospective 10-year growth of sawtimber and of all growing stock in forests of type-sites 1, 2, 3, and 4 managed under a thinning regime. The derivation and meaning of the estimates are explained on pages 63 to 66. The estimates were derived in the following form in which growth in percent of that represented in the Douglas-fir normal yield tables is related to stocking in percent of normal for any site class and stand age; the numbers are percentages:

| Stocking | Growth of sawtimber | Growth of all growing stock |
|---|---|---|
| 10 | 15 | 17 |
| 20 | 30 | 34 |
| 30 | 44 | 51 |
| 40 | 59 | 68 |
| 50 | 73 | 84 |
| 60 | 87 | 100 |
| 70 | 101 | 116 |
| 80 | 113 | 130 |
| 90 | 121 | 139 |
| 100 | 126 | 145 |
| 110 | 129 | 148 |
| 120 | 130 | 149 |

The estimates, in effect, are of gross growth. They may be compared with the analogous relationships for net growth which are estimated as follows for either sawtimber or all growing stock; the numbers, again, are percentages of normal:

| Stocking | Net growth |
|---|---|
| 10 | 15 |
| 20 | 29 |
| 30 | 42 |
| 40 | 54 |
| 50 | 65 |
| 60 | 75 |
| 70 | 83 |
| 80 | 90 |
| 90 | 96 |
| 100 | 100 |
| 110 | 102 |
| 120 | 103 |

Tables 41 and 42 are "empirical yield tables" derived by fitting, mathematically, second-degree curves to the basic inventory data on board foot volume per acre in relation to stand age, by type-site class. In table 41, all forest ownership classes are combined; in table 42, only National Forest data are used.

Table 33. — Estimated prospective 10-year growth of sawtimber in a type-site 1 forest under a thinning regime, by age and stocking

(In board feet per acre, Scribner rule)

| Age 30 | | Age 40 | | Age 50 | | Age 60 | | Age 70 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 260 | 1,400 | 1,190 | 2,330 | 2,740 | 2,310 | 4,280 | 2,160 | 5,720 | 1,920 |
| 520 | 2,790 | 2,380 | 4,650 | 5,480 | 4,620 | 8,560 | 4,320 | 11,440 | 3,840 |
| 780 | 4,090 | 3,570 | 6,820 | 8,220 | 6,780 | 12,840 | 6,340 | 17,160 | 5,630 |
| 1,040 | 5,490 | 4,760 | 9,150 | 10,960 | 9,090 | 17,120 | 8,500 | 22,880 | 7,550 |
| 1,300 | 6,790 | 5,950 | 11,320 | 13,700 | 11,240 | 21,400 | 10,510 | 28,600 | 9,340 |
| 1,560 | 8,090 | 7,140 | 13,490 | 16,440 | 13,400 | 25,680 | 12,530 | 34,320 | 11,140 |
| 1,820 | 9,390 | 8,330 | 15,660 | 19,180 | 15,550 | 29,960 | 14,540 | 40,040 | 12,930 |
| 2,080 | 10,510 | 9,520 | 17,520 | 21,920 | 17,400 | 34,240 | 16,270 | 45,760 | 14,460 |
| 2,340 | 11,250 | 10,710 | 18,760 | 24,660 | 18,630 | 38,520 | 17,420 | 51,480 | 15,490 |
| 2,600 | 11,720 | 11,900 | 19,530 | 27,400 | 19,400 | 42,800 | 18,100 | 57,200 | 16,130 |
| 2,860 | 12,000 | 13,090 | 20,000 | 30,140 | 19,870 | 47,080 | 18,580 | 62,920 | 15,510 |
| 3,120 | 12,090 | 14,280 | 20,150 | 32,880 | 20,020 | 51,360 | 18,720 | 68,640 | 16,640 |

| Age 80 | | Age 90 | | Age 100 | | Age 110 | | Age 120 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 7,000 | 1,650 | 8,100 | 1,410 | 9,040 | 1,190 | 9,830 | 1,020 | 10,510 | 890 |
| 14,000 | 3,300 | 16,200 | 2,820 | 18,080 | 2,370 | 19,660 | 2,040 | 21,020 | 1,770 |
| 21,000 | 4,840 | 24,300 | 4,140 | 27,120 | 3,480 | 29,490 | 2,990 | 31,530 | 2,600 |
| 28,000 | 6,490 | 32,400 | 5,550 | 36,160 | 4,660 | 39,320 | 4,010 | 42,040 | 3,480 |
| 35,000 | 8,030 | 40,500 | 6,860 | 45,200 | 5,770 | 49,150 | 4,960 | 52,550 | 4,310 |
| 42,000 | 9,570 | 48,600 | 8,180 | 54,240 | 6,870 | 58,980 | 5,920 | 63,060 | 5,130 |
| 49,000 | 11,110 | 56,700 | 9,490 | 63,280 | 7,980 | 68,810 | 6,870 | 73,570 | 5,960 |
| 56,000 | 12,430 | 64,800 | 10,620 | 72,320 | 8,930 | 78,640 | 7,680 | 84,080 | 6,670 |
| 63,000 | 13,310 | 72,900 | 11,370 | 81,360 | 9,560 | 88,470 | 8,230 | 94,590 | 7,140 |
| 70,000 | 13,860 | 81,000 | 11,800 | 90,400 | 9,950 | 98,300 | 8,570 | 105,100 | 7,430 |
| 77,000 | 14,190 | 89,100 | 12,130 | 99,440 | 10,190 | 108,130 | 8,770 | 115,610 | 7,610 |
| 84,000 | 14,300 | 97,200 | 12,220 | 108,480 | 10,270 | 117,960 | 8,840 | 126,120 | 7,670 |

Table 34. — Estimated prospective 10-year growth of sawtimber in a type-site 2 forest under a thinning regime, by age and stocking

(In board feet per acre, Scribner rule)

| Age 30 | | Age 40 | | Age 50 | | Age 60 | | Age 70 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 30 | 630 | 450 | 1,180 | 1,240 | 1,710 | 2,380 | 1,710 | 3,520 | 1,580 |
| 60 | 1,260 | 900 | 2,370 | 2,480 | 3,420 | 4,760 | 3,420 | 7,040 | 3,150 |
| 90 | 1,850 | 1,350 | 3,480 | 3,720 | 5,020 | 7,140 | 5,020 | 10,560 | 4,620 |
| 120 | 2,480 | 1,800 | 4,660 | 4,960 | 6,730 | 9,520 | 6,730 | 14,080 | 6,200 |
| 150 | 3,070 | 2,250 | 5,770 | 6,200 | 8,320 | 11,900 | 8,320 | 17,600 | 7,670 |
| 180 | 3,650 | 2,700 | 6,870 | 7,440 | 9,920 | 14,280 | 9,920 | 21,120 | 9,140 |
| 210 | 4,240 | 3,150 | 7,980 | 8,680 | 11,510 | 16,660 | 11,510 | 24,640 | 10,610 |
| 240 | 4,750 | 3,600 | 8,930 | 9,920 | 12,880 | 19,040 | 12,880 | 28,160 | 11,870 |
| 270 | 5,080 | 4,050 | 9,560 | 11,160 | 13,790 | 21,420 | 13,790 | 31,680 | 12,710 |
| 300 | 5,290 | 4,500 | 9,950 | 12,400 | 14,360 | 23,800 | 14,360 | 35,200 | 13,230 |
| 330 | 5,420 | 4,950 | 10,190 | 13,640 | 14,710 | 26,180 | 14,710 | 38,720 | 13,550 |
| 360 | 5,460 | 5,400 | 10,270 | 14,880 | 14,820 | 28,560 | 14,820 | 42,240 | 13,650 |

Table 34. — Estimated prospective 10-year growth of sawtimber in a type-site 2 forest under a thinning regime, by age and stocking—Continued

(In board feet per acre, Scribner rule)

| Age 80 | | Age 90 | | Age 100 | | Age 110 | | Age 120 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 4,570 | 1,400 | 5,500 | 1,170 | 6,280 | 990 | 6,940 | 840 | 7,500 | 750 |
| 9,140 | 2,790 | 11,000 | 2,340 | 12,560 | 1,980 | 13,880 | 1,680 | 15,000 | 1,500 |
| 13,710 | 4,100 | 16,500 | 3,440 | 18,840 | 2,900 | 20,820 | 2,460 | 22,500 | 2,200 |
| 18,280 | 5,490 | 22,000 | 4,600 | 25,120 | 3,890 | 27,760 | 3,300 | 30,000 | 2,950 |
| 22,850 | 6,790 | 27,500 | 5,690 | 31,400 | 4,820 | 34,700 | 4,090 | 37,500 | 3,650 |
| 27,420 | 8,090 | 33,000 | 6,790 | 37,680 | 5,740 | 41,640 | 4,870 | 45,000 | 4,350 |
| 31,990 | 9,390 | 38,500 | 7,880 | 43,960 | 6,670 | 48,580 | 5,660 | 52,500 | 5,050 |
| 36,560 | 10,510 | 44,000 | 8,810 | 50,240 | 7,460 | 55,520 | 6,330 | 60,000 | 5,650 |
| 41,130 | 11,250 | 49,500 | 9,440 | 56,520 | 7,990 | 62,460 | 6,780 | 67,500 | 6,050 |
| 45,700 | 11,720 | 55,000 | 9,830 | 62,800 | 8,320 | 69,400 | 7,060 | 75,000 | 6,300 |
| 50,270 | 12,000 | 60,500 | 10,060 | 69,080 | 8,510 | 76,340 | 7,220 | 82,500 | 6,450 |
| 54,840 | 12,090 | 66,000 | 10,140 | 75,360 | 8,580 | 83,280 | 7,280 | 90,000 | 6,500 |

Table 35. — Estimated prospective 10-year growth of sawtimber in a type-site 3 forest under a thinning regime, by age and stocking

(In board feet per acre, Scribner rule)

| Age 30 | | Age 40 | | Age 50 | | Age 60 | | Age 70 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| -- | -- | 20 | 470 | 330 | 720 | 810 | 890 | 1,400 | 920 |
| -- | -- | 40 | 930 | 660 | 1,440 | 1,620 | 1,770 | 2,800 | 1,830 |
| -- | -- | 60 | 1,360 | 990 | 2,110 | 2,430 | 2,600 | 4,200 | 2,680 |
| -- | -- | 80 | 1,830 | 1,320 | 2,830 | 3,240 | 3,480 | 5,600 | 3,600 |
| -- | -- | 100 | 2,260 | 1,650 | 3,500 | 4,050 | 4,310 | 7,000 | 4,450 |
| -- | -- | 120 | 2,700 | 1,980 | 4,180 | 4,860 | 5,130 | 8,400 | 5,310 |
| -- | -- | 140 | 3,130 | 2,310 | 4,850 | 5,670 | 5,960 | 9,800 | 6,160 |
| -- | -- | 160 | 3,500 | 2,640 | 5,420 | 6,480 | 6,670 | 11,200 | 6,890 |
| -- | -- | 180 | 3,750 | 2,970 | 5,810 | 7,290 | 7,140 | 12,600 | 7,380 |
| -- | -- | 200 | 3,910 | 3,300 | 6,050 | 8,100 | 7,430 | 14,000 | 7,690 |
| -- | -- | 220 | 4,000 | 3,630 | 6,190 | 8,910 | 7,610 | 15,400 | 7,870 |
| -- | -- | 240 | 4,030 | 3,960 | 6,240 | 9,720 | 7,670 | 16,800 | 7,930 |

| Age 80 | | Age 90 | | Age 100 | | Age 110 | | Age 120 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 2,010 | 890 | 2,600 | 810 | 3,140 | 740 | 3,630 | 660 | 4,070 | 600 |
| 4,020 | 1,770 | 5,200 | 1,620 | 6,280 | 1,470 | 7,260 | 1,320 | 8,140 | 1,200 |
| 6,030 | 2,600 | 7,800 | 2,380 | 9,420 | 2,160 | 10,890 | 1,940 | 12,210 | 1,760 |
| 8,040 | 3,480 | 10,400 | 3,190 | 12,560 | 2,890 | 14,520 | 2,600 | 16,280 | 2,360 |
| 10,050 | 4,310 | 13,000 | 3,940 | 15,700 | 3,580 | 18,150 | 3,210 | 20,350 | 2,920 |
| 12,060 | 5,130 | 15,600 | 4,700 | 18,840 | 4,260 | 21,780 | 3,830 | 24,420 | 3,480 |
| 14,070 | 5,960 | 18,200 | 5,450 | 21,980 | 4,950 | 25,410 | 4,440 | 28,490 | 4,040 |
| 16,080 | 6,670 | 20,800 | 6,100 | 25,120 | 5,540 | 29,040 | 4,970 | 32,560 | 4,520 |
| 18,090 | 7,140 | 23,400 | 6,530 | 28,260 | 5,930 | 32,670 | 5,320 | 36,630 | 4,840 |
| 20,100 | 7,430 | 26,000 | 6,800 | 31,400 | 6,170 | 36,300 | 5,540 | 40,700 | 5,040 |
| 22,110 | 7,610 | 28,600 | 6,970 | 34,540 | 6,320 | 39,930 | 5,680 | 44,770 | 5,160 |
| 24,120 | 7,670 | 31,200 | 7,020 | 37,680 | 6,370 | 43,560 | 5,720 | 48,840 | 5,200 |

Table 36. — Estimated prospective 10-year growth of sawtimber in a type-site 4 forest under a thinning regime, by age and stocking

(In board feet per acre, Scribner rule)

| Age 30 | | Age 40 | | Age 50 | | Age 60 | | Age 70 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| -- | -- | -- | -- | 160 | 480 | 480 | 630 | 900 | 735 |
| -- | -- | -- | -- | 320 | 960 | 960 | 1,260 | 1,800 | 1,470 |
| -- | -- | -- | -- | 480 | 1,408 | 1,440 | 1,848 | 2,700 | 2,156 |
| -- | -- | -- | -- | 640 | 1,888 | 1,920 | 2,478 | 3,600 | 2,891 |
| -- | -- | -- | -- | 800 | 2,336 | 2,400 | 3,066 | 4,500 | 3,577 |
| -- | -- | -- | -- | 960 | 2,784 | 2,880 | 3,654 | 5,400 | 4,263 |
| -- | -- | -- | -- | 1,120 | 3,232 | 3,360 | 4,242 | 6,300 | 4,949 |
| -- | -- | -- | -- | 1,280 | 3,616 | 3,840 | 4,746 | 7,200 | 5,537 |
| -- | -- | -- | -- | 1,440 | 3,872 | 4,320 | 5,082 | 8,100 | 5,929 |
| -- | -- | -- | -- | 1,600 | 4,032 | 4,800 | 5,292 | 9,000 | 6,174 |
| -- | -- | -- | -- | 1,760 | 4,128 | 5,280 | 5,418 | 9,900 | 6,321 |
| -- | -- | -- | -- | 1,920 | 4,160 | 5,760 | 5,460 | 10,800 | 6,370 |

| Age 80 | | Age 90 | | Age 100 | | Age 110 | | Age 120 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 1,390 | 705 | 1,860 | 630 | 2,280 | 585 | 2,670 | 555 | 3,040 | 510 |
| 2,780 | 1,410 | 3,720 | 1,260 | 4,560 | 1,170 | 5,340 | 1,100 | 6,080 | 1,020 |
| 4,170 | 2,068 | 5,580 | 1,848 | 6,840 | 1,716 | 8,010 | 1,628 | 9,120 | 1,496 |
| 5,560 | 2,773 | 7,440 | 2,478 | 9,120 | 2,301 | 10,680 | 2,183 | 12,160 | 2,006 |
| 6,950 | 3,431 | 9,300 | 3,066 | 11,400 | 2,847 | 13,350 | 2,701 | 15,200 | 2,482 |
| 8,340 | 4,089 | 11,160 | 3,654 | 13,680 | 3,393 | 16,020 | 3,219 | 18,240 | 2,958 |
| 9,730 | 4,747 | 13,020 | 4,242 | 15,960 | 3,939 | 18,690 | 3,737 | 21,280 | 3,434 |
| 11,120 | 5,311 | 14,880 | 4,746 | 18,240 | 4,407 | 21,360 | 4,181 | 24,320 | 3,842 |
| 12,510 | 5,687 | 16,740 | 5,082 | 20,520 | 4,719 | 24,030 | 4,477 | 27,360 | 4,114 |
| 13,900 | 5,922 | 18,600 | 5,292 | 22,800 | 4,914 | 26,700 | 4,662 | 30,400 | 4,284 |
| 15,290 | 6,063 | 20,460 | 5,418 | 25,080 | 5,031 | 29,370 | 4,773 | 33,440 | 4,386 |
| 16,680 | 6,110 | 22,320 | 5,460 | 27,360 | 5,070 | 32,040 | 4,810 | 36,480 | 4,420 |

Table 37. — Estimated prospective 10-year growth of sawtimber in a type-site 1 forest under a thinning regime, by age and stocking

(In cubic feet per acre)

| Age 30 | | Age 40 | | Age 50 | | Age 60 | | Age 70 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 330 | 470 | 600 | 390 | 830 | 360 | 1,040 | 300 | 1,220 | 260 |
| 650 | 940 | 1,200 | 780 | 1,660 | 710 | 2,080 | 600 | 2,430 | 530 |
| 980 | 1,400 | 1,800 | 1,170 | 2,490 | 1,070 | 3,120 | 890 | 3,650 | 790 |
| 1,300 | 1,870 | 2,400 | 1,560 | 3,320 | 1,430 | 4,160 | 1,190 | 4,860 | 1,050 |
| 1,630 | 2,310 | 3,000 | 1,930 | 4,150 | 1,760 | 5,200 | 1,470 | 6,080 | 1,300 |
| 1,950 | 2,750 | 3,600 | 2,300 | 4,980 | 2,100 | 6,240 | 1,750 | 7,290 | 1,550 |
| 2,280 | 3,190 | 4,200 | 2,670 | 5,810 | 2,440 | 7,280 | 2,030 | 8,510 | 1,800 |
| 2,600 | 3,580 | 4,800 | 2,990 | 6,640 | 2,730 | 8,320 | 2,280 | 9,720 | 2,020 |
| 2,930 | 3,820 | 5,400 | 3,200 | 7,470 | 2,920 | 9,360 | 2,430 | 10,940 | 2,160 |
| 3,250 | 3,990 | 6,000 | 3,340 | 8,300 | 3,050 | 10,400 | 2,540 | 12,150 | 2,250 |
| 3,580 | 4,070 | 6,600 | 3,400 | 9,130 | 3,110 | 11,440 | 2,590 | 13,370 | 2,290 |
| 3,900 | 4,100 | 7,200 | 3,430 | 9,960 | 3,130 | 12,480 | 2,610 | 14,580 | 2,310 |

Table 37. — Estimated prospective 10-year growth of sawtimber in a type-site 1 forest under a thinning regime, by age and stocking—Continued

(In cubic feet per acre)

| Age 80 | | Age 90 | | Age 100 | | Age 110 | | Age 120 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 1,370 | 230 | 1,510 | 190 | 1,620 | 150 | 1,710 | 120 | 1,780 | 110 |
| 2,740 | 460 | 3,010 | 370 | 3,230 | 310 | 3,410 | 240 | 3,550 | 220 |
| 4,110 | 690 | 4,520 | 560 | 4,850 | 460 | 5,120 | 360 | 5,330 | 330 |
| 5,480 | 920 | 6,020 | 750 | 6,460 | 610 | 6,820 | 480 | 7,100 | 440 |
| 6,850 | 1,130 | 7,530 | 920 | 8,080 | 760 | 8,530 | 590 | 8,880 | 550 |
| 8,220 | 1,350 | 9,030 | 1,100 | 9,690 | 900 | 10,230 | 700 | 10,650 | 650 |
| 9,590 | 1,570 | 10,540 | 1,280 | 11,310 | 1,040 | 11,940 | 810 | 12,430 | 750 |
| 10,960 | 1,760 | 12,040 | 1,430 | 12,920 | 1,170 | 13,640 | 910 | 14,200 | 850 |
| 12,330 | 1,880 | 13,550 | 1,530 | 14,540 | 1,250 | 15,350 | 970 | 15,980 | 900 |
| 13,700 | 1,960 | 15,050 | 1,600 | 16,150 | 1,310 | 17,050 | 1,020 | 17,750 | 940 |
| 15,070 | 2,000 | 16,560 | 1,630 | 17,770 | 1,330 | 18,760 | 1,040 | 19,530 | 960 |
| 16,440 | 2,010 | 18,060 | 1,640 | 19,380 | 1,340 | 20,460 | 1,040 | 21,300 | 970 |

Table 38. — Estimated prospective 10-year growth of sawtimber in a type-site 2 forest under a thinning regime, by age and stocking

(In cubic feet per acre)

| Age 30 | | Age 40 | | Age 50 | | Age 60 | | Age 70 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 210 | 370 | 430 | 350 | 640 | 310 | 820 | 260 | 970 | 200 |
| 420 | 750 | 860 | 700 | 1,270 | 610 | 1,630 | 510 | 1,930 | 410 |
| 630 | 1,120 | 1,290 | 1,050 | 1,910 | 920 | 2,450 | 770 | 2,900 | 610 |
| 840 | 1,500 | 1,720 | 1,390 | 2,540 | 1,220 | 3,260 | 1,020 | 3,860 | 820 |
| 1,050 | 1,850 | 2,150 | 1,720 | 3,180 | 1,510 | 4,080 | 1,260 | 4,830 | 1,010 |
| 1,260 | 2,200 | 2,580 | 2,050 | 3,810 | 1,800 | 4,890 | 1,500 | 5,790 | 1,200 |
| 1,470 | 2,550 | 3,010 | 2,380 | 4,450 | 2,090 | 5,710 | 1,740 | 6,760 | 1,390 |
| 1,680 | 2,860 | 3,440 | 2,670 | 5,080 | 2,340 | 6,520 | 1,950 | 7,720 | 1,560 |
| 1,890 | 3,060 | 3,870 | 2,850 | 5,720 | 2,500 | 7,340 | 2,090 | 8,690 | 1,670 |
| 2,100 | 3,190 | 4,300 | 2,970 | 6,350 | 2,610 | 8,150 | 2,180 | 9,650 | 1,740 |
| 2,310 | 3,260 | 4,730 | 3,030 | 6,990 | 2,660 | 8,970 | 2,220 | 10,620 | 1,780 |
| 2,520 | 3,280 | 5,160 | 3,060 | 7,620 | 2,680 | 9,780 | 2,240 | 11,580 | 1,790 |

| Age 80 | | Age 90 | | Age 100 | | Age 110 | | Age 120 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 1,090 | 180 | 1,190 | 150 | 1,280 | 130 | 1,360 | 100 | 1,420 | 90 |
| 2,170 | 360 | 2,380 | 310 | 2,560 | 260 | 2,710 | 200 | 2,830 | 190 |
| 3,260 | 540 | 3,570 | 460 | 3,840 | 380 | 4,070 | 310 | 4,250 | 280 |
| 4,340 | 710 | 4,760 | 610 | 5,120 | 510 | 5,420 | 410 | 5,660 | 370 |
| 5,430 | 880 | 5,950 | 760 | 6,400 | 630 | 6,780 | 500 | 7,080 | 460 |
| 6,510 | 1,050 | 7,140 | 900 | 7,680 | 750 | 8,130 | 600 | 8,490 | 550 |
| 7,600 | 1,220 | 8,330 | 1,040 | 8,960 | 870 | 9,490 | 700 | 9,910 | 640 |
| 8,680 | 1,370 | 9,520 | 1,170 | 10,240 | 980 | 10,840 | 780 | 11,320 | 720 |
| 9,770 | 1,470 | 10,710 | 1,250 | 11,520 | 1,040 | 12,200 | 830 | 12,740 | 770 |
| 10,850 | 1,520 | 11,900 | 1,310 | 12,800 | 1,090 | 13,550 | 870 | 14,150 | 800 |
| 11,940 | 1,550 | 13,090 | 1,330 | 14,080 | 1,110 | 14,910 | 890 | 15,570 | 810 |
| 13,020 | 1,570 | 14,280 | 1,340 | 15,360 | 1,120 | 16,260 | 890 | 16,980 | 820 |

Table 39. — Estimated prospective 10-year growth of sawtimber in a type-site 3 forest under a thinning regime, by age and stocking

(In cubic feet per acre)

| Age 30 | | Age 40 | | Age 50 | | Age 60 | | Age 70 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 110 | 220 | 240 | 250 | 380 | 240 | 520 | 200 | 640 | 160 |
| 210 | 440 | 470 | 490 | 760 | 480 | 1,040 | 390 | 1,270 | 320 |
| 320 | 660 | 710 | 740 | 1,140 | 710 | 1,560 | 590 | 1,910 | 480 |
| 420 | 880 | 940 | 990 | 1,520 | 950 | 2,080 | 780 | 2,540 | 650 |
| 530 | 1,090 | 1,180 | 1,220 | 1,900 | 1,180 | 2,600 | 970 | 3,180 | 800 |
| 630 | 1,300 | 1,410 | 1,450 | 2,280 | 1,400 | 3,120 | 1,150 | 3,810 | 950 |
| 740 | 1,510 | 1,650 | 1,680 | 2,660 | 1,620 | 3,640 | 1,330 | 4,450 | 1,100 |
| 840 | 1,690 | 1,880 | 1,890 | 3,040 | 1,820 | 4,160 | 1,500 | 5,080 | 1,240 |
| 950 | 1,810 | 2,120 | 2,020 | 3,420 | 1,950 | 4,680 | 1,600 | 5,720 | 1,320 |
| 1,050 | 1,890 | 2,350 | 2,100 | 3,800 | 2,030 | 5,200 | 1,670 | 6,350 | 1,380 |
| 1,160 | 1,920 | 2,590 | 2,150 | 4,180 | 2,070 | 5,720 | 1,700 | 6,990 | 1,410 |
| 1,260 | 1,940 | 2,820 | 2,160 | 4,560 | 2,090 | 6,240 | 1,710 | 7-620 | 1,420 |

| Age 80 | | Age 90 | | Age 100 | | Age 110 | | Age 120 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 730 | 130 | 810 | 100 | 870 | 90 | 920 | 70 | 960 | 70 |
| 1,460 | 260 | 1,610 | 200 | 1,730 | 190 | 1,840 | 140 | 1,920 | 140 |
| 2,190 | 380 | 2,420 | 310 | 2,600 | 280 | 2,760 | 200 | 2,880 | 200 |
| 2,920 | 510 | 3,220 | 410 | 3,460 | 370 | 3,680 | 270 | 3,840 | 270 |
| 3,650 | 630 | 4,030 | 500 | 4,330 | 460 | 4,600 | 340 | 4,800 | 340 |
| 4,380 | 750 | 4,830 | 600 | 5,190 | 550 | 5,520 | 400 | 5,760 | 400 |
| 5,110 | 870 | 5,640 | 700 | 6,060 | 640 | 6,440 | 460 | 6,720 | 460 |
| 5,840 | 980 | 6,440 | 780 | 6,920 | 720 | 7,360 | 520 | 7,680 | 520 |
| 6,570 | 1,040 | 7,250 | 830 | 7,790 | 770 | 8,280 | 560 | 8,640 | 560 |
| 7,300 | 1,090 | 8,050 | 870 | 8,650 | 800 | 9,200 | 580 | 9,600 | 580 |
| 8,030 | 1,110 | 8,860 | 890 | 9,520 | 810 | 10,120 | 590 | 10,560 | 590 |
| 8,760 | 1,120 | 9,660 | 890 | 10,380 | 820 | 11,040 | 600 | 11,520 | 600 |

Table 40. — Estimated prospective 10-year growth of sawtimber in a type-site 4 forest under a thinning regime, by age and stocking

(In cubic feet per acre)

| Age 30 | | Age 40 | | Age 50 | | Age 60 | | Age 70 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 80 | 170 | 180 | 204 | 300 | 221 | 430 | 170 | 530 | 153 |
| 160 | 340 | 360 | 408 | 600 | 442 | 860 | 340 | 1,060 | 306 |
| 240 | 510 | 540 | 612 | 900 | 663 | 1,290 | 510 | 1,590 | 459 |
| 320 | 680 | 720 | 816 | 1,200 | 884 | 1,720 | 680 | 2,120 | 612 |
| 400 | 840 | 900 | 1,008 | 1,500 | 1,092 | 2,150 | 840 | 2,650 | 756 |
| 480 | 1,000 | 1,080 | 1,200 | 1,800 | 1,300 | 2,580 | 1,000 | 3,180 | 900 |
| 560 | 1,160 | 1,260 | 1,392 | 2,100 | 1,508 | 3,010 | 1,160 | 3,710 | 1,044 |
| 640 | 1,300 | 1,440 | 1,560 | 2,400 | 1,690 | 3,440 | 1,300 | 4,240 | 1,170 |
| 720 | 1,390 | 1,620 | 1,668 | 2,700 | 1,807 | 3,870 | 1,390 | 4,770 | 1,251 |
| 800 | 1,450 | 1,800 | 1,740 | 3,000 | 1,885 | 4,300 | 1,450 | 5,300 | 1,305 |
| 880 | 1,480 | 1,980 | 1,776 | 3,300 | 1,924 | 4,730 | 1,480 | 5,830 | 1,332 |
| 960 | 1,490 | 2,160 | 1,788 | 3,600 | 1,937 | 5,160 | 1,490 | 6,360 | 1,341 |

Table 40. — Estimated prospective 10-year growth of sawtimber in a type-site 4 forest under a thinning regime, by age and stocking—Continued

(In cubic feet per acre)

| Age 80 | | Age 90 | | Age 100 | | Age 110 | | Age 120 | |
|---|---|---|---|---|---|---|---|---|---|
| Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth | Stocking | Growth |
| 620 | 102 | 680 | 85 | 730 | 85 | 780 | 60 | 815 | 51 |
| 1,240 | 204 | 1,360 | 170 | 1,460 | 170 | 1,560 | 119 | 1,630 | 102 |
| 1,860 | 306 | 2,040 | 255 | 2,190 | 255 | 2,340 | 179 | 2,445 | 153 |
| 2,480 | 408 | 2,720 | 340 | 2,920 | 340 | 3,120 | 238 | 3,260 | 204 |
| 3,100 | 504 | 3,400 | 420 | 3,650 | 420 | 3,900 | 294 | 4,075 | 252 |
| 3,720 | 600 | 4,080 | 500 | 4,380 | 500 | 4,680 | 350 | 4,890 | 300 |
| 4,340 | 696 | 4,760 | 580 | 5,110 | 580 | 5,460 | 406 | 5,705 | 348 |
| 4,960 | 780 | 5,440 | 650 | 5,840 | 650 | 6,240 | 455 | 6,520 | 390 |
| 5,580 | 834 | 6,120 | 695 | 6,570 | 695 | 7,020 | 487 | 7,335 | 417 |
| 6,200 | 870 | 6,800 | 725 | 7,300 | 725 | 7,800 | 508 | 8,150 | 435 |
| 6,820 | 888 | 7,480 | 740 | 8,030 | 740 | 8,580 | 518 | 8,965 | 444 |
| 7,440 | 894 | 8,160 | 745 | 8,760 | 745 | 9,360 | 522 | 9,780 | 447 |

Table 41. — Estimated quantity of live sawtimber per acre of commercial forest land in the Puget Sound and Columbia River districts, by type-site class and stand age, decade of 1950's

(In thousand board feet)

| Stand age (years) | Type-site class | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 30 | 4.0 | 3.1 | 0.5 | -- | -- |
| 40 | 12.5 | 8.6 | 3.6 | 2.4 | 6.1 |
| 50 | 20.8 | 13.9 | 7.3 | 5.6 | 11.4 |
| 60 | 28.6 | 19.0 | 10.8 | 8.6 | 15.5 |
| 70 | 36.1 | 23.9 | 14.1 | 11.5 | 19.2 |
| 80 | 43.3 | 28.6 | 17.3 | 14.4 | 22.0 |
| 90 | 50.1 | 33.1 | 20.4 | 17.2 | 24.5 |
| 100 | 56.5 | 37.3 | 23.3 | 19.9 | 26.3 |
| 110 | 62.6 | 41.4 | 26.1 | 22.5 | 27.5 |
| 120 | 68.3 | 45.2 | 28.7 | 25.0 | 28.2 |
| 130 | 73.7 | 48.8 | 31.2 | 27.4 | 28.4 |
| 140 | 78.7 | 52.2 | 33.6 | 29.8 | -- |
| 150 | 83.3 | 55.4 | 35.8 | 32.0 | -- |
| 160 | 87.6 | 58.4 | 37.9 | 34.2 | -- |
| 170 | 91.6 | 61.2 | 39.8 | 36.3 | -- |
| 180 | 95.1 | 63.8 | 41.6 | 38.3 | -- |
| 190 | 98.4 | 66.1 | 43.2 | 40.2 | -- |
| 200 | 101.2 | 68.3 | 44.7 | 42.0 | -- |
| 210 | 103.7 | 70.2 | 46.1 | 43.7 | -- |
| 220 | 105.9 | 71.9 | 47.3 | 45.4 | -- |
| 230 | 107.6 | 73.4 | 48.4 | 47.0 | -- |
| 240 | 109.1 | 74.7 | 49.3 | 48.4 | -- |
| 250 | 110.2 | 75.8 | 50.1 | 49.8 | - |
| 260 | 110.9 | 76.7 | 50.8 | 51.2 | -- |
| 270 | 111.2 | 77.4 | 51.3 | 52.4 | - |
| 280 | 111.2 | 77.8 | 51.6 | 53.5 | -- |
| 290 | -- | 78.1 | 51.9 | 54.6 | -- |
| 300 | -- | 78.1 | 52.0 | 55.5 | -- |
| 310 | -- | -- | -- | 56.4 | -- |
| 320 | -- | -- | -- | 57.2 | -- |
| 330 | -- | -- | -- | 57.9 | -- |
| 340 | -- | -- | -- | 58.6 | -- |
| 350 | -- | -- | -- | 59.1 | -- |

Table 42. — Estimated quantity of live sawtimber per acre of commercial forest land on national forests in the Southwest Oregon district, by type-site class and stand age, decade of 1950's

(In thousand board feet)

| Stand age (years) | Type-site class | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 30 | 7.1 | 5.3 | 0.5 | -- | -- |
| 40 | 12.1 | 8.8 | 3.2 | 0.9 | 0.6 |
| 50 | 16.8 | 12.3 | 5.9 | 3.3 | 1.6 |
| 60 | 21.4 | 15.6 | 8.4 | 5.7 | 2.6 |
| 70 | 25.7 | 18.8 | 10.9 | 8.1 | 3.5 |
| 80 | 29.8 | 21.9 | 13.2 | 10.4 | 4.4 |
| 90 | 33.6 | 24.8 | 15.4 | 12.6 | 5.3 |
| 100 | 37.3 | 27.6 | 17.6 | 14.8 | 6.2 |
| 110 | 40.7 | 30.3 | 19.6 | 16.9 | 7.0 |
| 120 | 43.9 | 32.8 | 21.5 | 19.0 | 7.8 |
| 130 | 46.9 | 35.3 | 23.3 | 21.1 | 8.6 |
| 140 | 49.7 | 37.6 | 25.0 | 23.1 | 9.4 |
| 150 | 52.3 | 39.7 | 26.6 | 25.0 | 10.2 |
| 160 | 54.7 | 41.8 | 28.0 | 26.9 | 11.0 |
| 170 | 56.8 | 43.7 | 29.4 | 28.7 | 11.8 |
| 180 | 58.7 | 45.5 | 30.6 | 30.5 | 12.6 |
| 190 | 60.4 | 47.1 | 31.8 | 32.3 | 13.4 |
| 200 | 61.9 | 48.6 | 32.8 | 34.0 | 14.1 |
| 210 | 63.2 | 50.0 | 33.8 | 35.6 | -- |
| 220 | 64.2 | 51.3 | 34.6 | 37.2 | -- |
| 230 | 65.1 | 52.4 | 35.3 | 38.8 | -- |
| 240 | 65.7 | 53.4 | 35.9 | 40.3 | -- |
| 250 | 66.1 | 54.3 | 36.4 | 41.7 | -- |
| 260 | 66.2 | 55.1 | 36.8 | 43.1 | -- |
| 270 | 66.2 | 55.7 | 37.1 | 44.5 | -- |
| 280 | -- | 56.2 | 37.3 | 45.8 | -- |
| 290 | -- | 56.6 | 37.4 | 47.0 | -- |
| 300 | -- | 56.8 | -- | 48.2 | -- |
| 310 | -- | 56.9 | -- | 49.4 | -- |
| 320 | -- | -- | -- | 50.5 | -- |
| 330 | -- | -- | -- | 51.5 | -- |
| 340 | -- | -- | -- | 52.5 | -- |
| 350 | - | - | -- | 53.5 | - |

# Appendix C

## Future Projections of Present Trends

The detailed timber inventory of the 1950's was projected in 10-year steps to the year 2000 in a detailed projection of cut and growth, making allowance for shifts in landownership and use, losses from fire and catastrophic mortality, reforestation of nonstocked areas, and extra yields from thinning, salvage, prelogging, and relogging.

A summary projection of yield was then carried further from the year 2000 through 2070 to complete an entire rotation on all ownership classes. Individual summary projections were in the form of a conventional area-volume check for each ownership class in each geographic district.

The projection of present trends assumed continuation of current allowable cuts on all public forests and a cutting rate on private lands corresponding to their average cutting rate for the 3 years 1955 to 1957 taken as a percentage of growing stock. Reforestation, salvage of mortality, thinning, prelogging, and relogging were assumed to increase at a modest rate to the year 2000. These rates were different for each ownership class.

Tables 52 and 54 at the end of this appendix show projected yields in the three geographic districts during the four decades 1960-2000 under the projection of present trends. They represent a more detailed breakdown of table 20.

Figures 19 to 24 diagram the projected age-class distributions in 1960 and the year 2000.

## Detailed Projections, 1960-2000

The first step in the detailed projections was to update the basic timber inventory of Appendix A to 1960. In the Puget Sound and Columbia River districts, the inventory of the 1950's was taken to represent 1955 and therefore updated 5 years to 1960 by taking into account actual cuts and estimated growth, shifts in landownership and use, fire and catastrophic losses, and reforestation. In the Southwest Oregon district, the actual National Forest inventory was for 1960, and the inventory for other holdings was taken to represent 1950 and updated 10 years to 1960.

The starting inventory was recorded on worksheets showing area and board foot volume for each 20-year age class of every type-site and ownership class for all geographic districts. Every individual entry was termed a projection unit. The identity of each of these projection units was maintained throughout the detailed projection.

The projection procedure was to apply the estimated shifts in landownership and use, losses by fire and catastrophic mortality, yields from thinning, salvage,

prelogging and relogging, and estimated harvest cuts, for each ownership class in each geographic district, to the area and volume inventory of that ownership class for each decade. Growth of the residual stand was then projected to the end of the decade. This procedure was repeated for successive decades to the year 2000.

Growth was estimated from the empirical yield tables of Appendix B. In order to reflect the fact that the 10-year cut would be spread uniformly over the 10 years, one-half of the 10 years' growth was included in the cut for all the area harvested in each decade as part of the harvest yield.

## Withdrawals and Shifts in Ownership

Estimated forest land withdrawals and shifts in ownership (see chapter 2) were taken into account uniformly for each decade over the projection period so as to be completed by the year 2000. They were applied at the beginning of each decade before application of cut and growth. In the case of withdrawals for roads and reservoirs, the timber on the withdrawn areas was taken as part of the cut for the decade. Withdrawals and shifts were proportioned among the age classes on the basis of area.

## Losses from Fire and Catastrophic Mortality

The following tabulation shows the factors used to estimate annual timber mortality from fire and catastrophic loss:

| Decade | Stands 1-35 years | Stands over 35 years |
|---|---|---|
| | (Percent of acreage in each age class) | |
| 1950's | 0.282 | 0.134 |
| 1960's | .231 | .126 |
| 1970's | .210 | .108 |
| 1980's | .187 | .100 |
| 1990's | .166 | .092 |
| 2000's | .152 | .087 |

Separate factors were developed for stands under 35 years of age to reflect the greater likelihood of fire occurring in younger stands. Acreage fire losses were based on the 10-year experience of 1948-57. Indicated reductions in the rate of loss are consistent with those used in Timber Resources for America's Future (15, table 279, p. 470).

Catastrophic losses were calculated to have averaged 0.050 percent of commercial forest area per year since 1902. This factor was added uniformly to acreage fire-loss estimates to produce the combined factors shown above.

Estimated volumes salvaged in percent of timber killed by fire or catastrophic loss were determined as follows:

| Decade | Present-trends projection |
|---|---|
| 1950's | 50 |
| 1960's | 50 |
| 1970's | 55 |
| 1980's | 60 |
| 1990's | 70 |

The percentage of salvage is higher in the later years due to anticipated improvements in access and in utilization.

## Estimation of Harvest Cuts

Harvest cuts used in the projection included estimates of only the live timber volumes harvested and the estimated salvageable volumes of timber killed by fire and other catastrophe. Extra yields from thinnings, salvage of accumulated and annual mortality, and prelogging and relogging were estimated separately as a supplement to the regular harvest cuts.

Annual harvest cuts on public holdings were assumed to be the allowable cuts reported by the respective managing agencies. For county, municipal, and some State and other public agencies not reporting allowable cuts, the annual cuts were estimated by using rates similar to corresponding properties elsewhere. Except when they were reported otherwise, the annual allowable cuts were assumed to hold for the entire period from 1960 to 2000.

Private harvest cuts were tentatively estimated as a percent of growing stock, using the actual average annual percentage for the 3 years, 1955-57. These percentages were then modified for individual ownership classes to reflect their generally different cutting rates. Large private ownerships were assigned a rate lower than the average. Small private ownerships were assigned a cutting rate above the average. Medium private ownerships were assigned an intermediate rate, generally closer to the rate for the large private ownerships. These rates were determined for each geographic district in such a way that their weighted average would equal the overall percentage first tentatively estimated for all private ownerships combined. The results, used in all four decades, are given in table 43.

The indicated harvest cuts, as described in the two paragraphs above, were applied to the area and volume, by age-class, remaining after area and volume to be given thinning treatment were taken out. The volume of any final clear cut of previously thinned areas was considered chargeable to these indicated harvest cuts.

Table 43. — Assumed annual cutting rates (percent of growing stock) on private holdings

| Size Class | Puget Sound | Columbia River | Southwest Oregon |
|---|---|---|---|
| | | Percent | |
| Large | 2.0 | 2.5 | 4.0 |
| Medium | 3.0 | 3.5 | 4.5 |
| Small | 3.7 | 4.8 | 6.0 |
| All classes | 2.4 | 3.3 | 4.7 |

Table 44. — Economic rotation ages, saw log objective

| Type-site | Conservative owner | Intermediate owner | Exploitive owner |
|---|---|---|---|
| | | Years | |
| 1 | 70 | 55 | 45 |
| 2 | 80 | 60 | 50 |
| 3 | 90 | 75 | 55 |
| 4 | 95 | 80 | 60 |

Yields from thinnings, mortality salvage, prelogging, and relogging were estimated separately from harvest cuts. These will be discussed at a later point.

## Distribution of Cut Among Type-Site Classes

In allocating the harvest cut (excluding thinnings, salvage, and prelogging yields) among type-site classes, the hardwood cut was determined separately, and the balance distributed among the conifer type-site classes. The hardwood cut in type-site 5 was estimated as a percentage of hardwood inventory volume, as follows:

| Decade | Percent |
|---|---|
| 1950's | 0.5 |
| 1960's | .7 |
| 1970's | .9 |
| 1980's | 1.0 |
| 1990's | 1.5 |
| 2000's | 2.0 |

Analysis of data on hardwood utilization indicated that the current hardwood cut in the Douglas-fir subregion was approximately 0.5 percent of the current inventory in type-site 5. This percent was increased to 1.5 percent for the 1990's to allow for the trend toward increased utilization of hardwoods.

Within each ownership class, the conifer cut was allocated among the four conifer type-site classes in proportion to their inventory volume, except for type-site 4 where a reduction factor was applied to reflect the presently less intensive util-

ization of upper-slope types (table 45). For example, with a one-third factor, one-third of the volume in type-site 4 would be added to the volumes in other conifer type-sites, with the cut distributed in proportion to each type-site's proportion of this total.

Table 45. — Factors applied in allocating cut to type-site 4

| Decade | Present-trends projection public and private owners |
|---|---|
| 1960's | 1/3 |
| 1970's | 1/2 |
| 1980's | 2/3 |
| 1990's | 3/4 |

## Distribution of Cut Among Age-Classes

Allocation of the indicated harvest cut was made among a wide range of age classes for each type-site and ownership class, except for the hardwood types where for simplicity the cuts were all taken from the oldest age classes. For small private ownerships, the cut was taken first to include 2 percent of the area and volume in each age class 40 years old and over; then, the remainder of the indicated harvest cut was taken from the oldest age classes.

For all other ownerships, the cut included 1 percent of the area and volume in each age class 160 years old and older, with the remainder taken from the oldest age classes.

None of the harvest cut was taken from age classes below the indicated economic rotation ages (table 44) for each ownership class and type-site class. Occasionally, therefore, the actual cut used in the projection was somewhat less than the indicated harvest cut for those private ownerships and type-sites where excess of old growth was small.

## Yields from Thinning, Salvage of Mortality, Prelogging, and Relogging

Thinning yields.—Thinning yields were estimated according to basic data of tables 33 through 36, Appendix B, reduced for cull and breakage. Thinnings were assumed to begin in 30-year and older stands and to be repeated each decade until final harvest in the decade following attainment of rotation age. Thinnings on National Forests were assumed to continue until age of culmination of mean annual increment, as shown in the normal yield tables for Scribner board foot log volumes in trees 11.0 inches in diameter and over.

Table 46 shows the estimated percentage of the immature sawtimber area thinned in each decade.

Table 46. — Assumed proportion of immature sawtimber area to be managed under a thinning regime, by ownership class, type-site class, and decade

| Decade | Private holdings | | | | | | Public holdings | |
|---|---|---|---|---|---|---|---|---|
| | Large | | Medium | | Small | | | |
| | Type-sites 1 & 2 | Type-sites 3 & 4 | Type-sites 1 & 2 | Type-sites 3 & 4 | Type-sites 1 & 2 | Type-sites 3 & 4 | Type-sites 1 & 2 | Type-sites 3 & 4 |
| | Percent | | | | | | | |
| 1960's | 15 | 0 | 15 | 0 | 5 | 0 | 5 | 0 |
| 1970's | 20 | 0 | 20 | 0 | 10 | 0 | 10 | 0 |
| 1980's | 35 | 0 | 35 | 0 | 15 | 0 | 15 | 0 |
| 1990's | 50 | 0 | 50 | 0 | 20 | 0 | 25 | 0 |

It was assumed that thinnings would be made in hardwood types. The percentages apply to the acreage in each age class between the age of initial thinning and rotation age. Calculated areas to be thinned in each ownership class were allocated among conservative and intermediate owners, as follows:

| Owner class | Conservative owners (Percent) | Intermediate owners (Percent) |
|---|---|---|
| Large private | 85 | 15 |
| Medium private | 20 | 80 |
| Small private | 0 | 100 |
| National Forests | 100 | 0 |
| Other Federal | 85 | 15 |
| Other public | 60 | 40 |

Growing stock on thinned areas approximated 60 percent of normal at time of final harvest. This was a result of the thinning program used in the projections. As this is very close to the stocking shown in the empirical yield tables for unthinned stands and in the absence of more definitive information on influence of thinning on final yields, none of the thinning yields were considered chargeable to the indicated harvest cuts. That is, although thinned stands would have less volume at time of final harvest than would the same stands without the last one or two thinnings, it is judged that they probably would have more usable net volume as a result of early thinning than if they had never been thinned, so that none of the thinned volume should, strictly speaking, be chargeable.

Salvage yields.—It was assumed that all except small private owners would construct advance roads to salvage accumulated mortality in stands 120 years and older on type-site classes 1 and 2 and in stands 200 years and older on type-site classes 3 and 4. Initial salvage yields were estimated at 10,000 board feet per acre for type-site 1 and 2 stands over 200 years old and at 5,000 for those 120 to 200 years old. Initial salvage yields from type-sites 3 and 4 were estimated at 5,000 board feet per acre.

Table 47. — Percent of old growth to be advance salvaged as dead material

| Decade | Owner class | |
|---|---|---|
| | Large and medium private | All public |
| 1960's | 10 | 5 |
| 1970's | 15 | 10 |
| 1980's | 20 | 15 |
| 1990's | 25 | 20 |

Whenever application of percentages in table 47 produced an area less than that given advance salvage in the previous decade, the area salvaged was increased to that of the previous decade.

All stands previously given advance salvage were assumed to be reworked each decade for salvage of subsequent mortality. Salvage yields were estimated at 80 percent of the periodic mortality after reduction for cull and breakage. Mortality was estimated as the difference between gross growth and net growth per acre given by the empirical yield tables of Appendix B. Table 48 lists estimated net salvage yields.

Table 48. — Net board foot yields per acre from salvage of previous 10-year mortality

(In thousand board feet per acre)

| Age | Type-site class | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 120 | 2.6 | 1.4 | -- | -- |
| 130 | 2.2 | 1.4 | -- | -- |
| 140 | 2.0 | 1.4 | -- | -- |
| 150 | 1.8 | 1.4 | -- | -- |
| 160 | 1.7 | 1.4 | -- | -- |
| 170 | 1.8 | 1.5 | -- | -- |
| 180 | 1.8 | 1.6 | -- | -- |
| 190 | 1.9 | 1.7 | -- | -- |
| 200 | 2.1 | 1.8 | 0.8 | 0.4 |
| 210 | 2.2 | 1.9 | 1.0 | .4 |
| 220 | 2.4 | 2.1 | 1.0 | .5 |
| 230 | 2.6 | 2.2 | 1.1 | .6 |
| 240 | 2.8 | 2.4 | 1.3 | .6 |
| 250 | 3.0 | 2.6 | 1.4 | .6 |
| 260 | 3.2 | 2.7 | 1.5 | .7 |
| 270 | 3.4 | 2.9 | 1.6 | .8 |
| 280 | 3.5 | 3.0 | 1.8 | .9 |
| 290 | 3.7 | 3.2 | 1.8 | 1.0 |
| 300 | 3.8 | 3.4 | 2.0 | 1.0 |
| 310 | 4.0 | 3.5 | 2.1 | 1.1 |
| 320 | 4.1 | 3.7 | 2.2 | 1.1 |
| 330 | 4.2 | 3.8 | 2.3 | 1.2 |
| 340 | 4.2 | 4.0 | 2.4 | 1.3 |

The salvage of mortality existing on clear-cut areas, harvested along with the live cut, was calculated and made a part of harvest cut. These yields were calculated the same as for advance salvage of mortality.

Prelogging and relogging yields.—Prelogging and relogging in stands of high volume per acre increase yields over single stage clear cutting. The extra volume is realized through reduced breakage, and through utilization of tops, small trees, and cull logs not included in the live sawtimber inventory. Much of the material is of pulpwood quality. Table 49 shows percent of clear-cut stands of 40,000 board feet per acre and over that were assumed to be prelogged or relogged. These additional yields were estimated at 10 percent of the net volume per acre.

Table 49. — Percent of clear-cut stands over 40,000 board feet per acre relogged or prelogged

| Decade | Large and medium private | Small private | Public owners |
|---|---|---|---|
| 1960's | 10 | 0 | 5 |
| 1970's | 20 | 0 | 10 |
| 1980's | 30 | 0 | 15 |
| 1990's | 40 | 0 | 20 |

## Reforestation

Old burns and cutovers.—Table 50 presents the rate at which the backlog of nonrestocked areas were estimated to become successfully reforested. Areas restocked in each decade were assigned an average age of 5 years at the beginning of the following decade.

Table 50. — Cumulative percent of 1955 backlog of old burns and cutovers reforested

| | Private owners | | | |
|---|---|---|---|---|
| Decade | Large | Medium | Small | Public owners |
| 1950's | 5 | 5 | 0 | 5 |
| 1960's | 30 | 30 | 15 | 30 |
| 1970's | 60 | 60 | 30 | 60 |
| 1980's | 70 | 70 | 40 | 65 |
| 1990's | 75 | 75 | 50 | 70 |

New burns and cutovers.—Current burns were considered to be reforested at the same rate as current cutovers in any decade. Table 51 was used to establish the rate of successful reforestation of new burns and cutovers.

Table 51. — Years of delay until successful reforestation of new cutovers and new burns

| Small private owners | | All other owners | |
|---|---|---|---|
| Percent of area | Years of delay | Percent of area | Years of delay |
| 75 | 0-9 | 100 | 0-10 |
| 25 | 10 | | |

## Review of Projection Procedure

Individual steps in the projection procedure for a single decade are reviewed in the following listing:

1. Area and volume inventory was adjusted for all the age classes of each type-site, ownership class, and geographic district at the beginning of each decade, to take into account shifts in landownership and use. The type-site changes were distributed by age class according to area in each age class.

2. Areas and volumes lost from fire and catastrophic mortality were deducted. Volume salvaged from this source was calculated and included as part of the indicated harvest cut.

3. Area to be managed under a thinning regime was calculated and split into conservative and intermediate owners, and thinning yields were calculated. Any final cuts of thinned areas were included as part of the indicated harvest cut.

4. Cut of type-site 5 was calculated and taken from oldest age classes.

5. Cuts of type-sites 1 to 4 were calculated separately and taken from age classes 40 and over (small private ownerships) or 160 and over (other ownerships). Then the remainder of indicated harvest cut was taken from oldest age classes.

6. One-half of the 10 years' growth on cut areas was included as part of the indicated harvest cuts of steps 4 and 5.

7. Growth from empirical yield tables was applied to remaining inventory of unthinned areas. Growth from thinning schedules was applied to residual thinned stands. This gave starting inventory for the next decade.

8. Volumes of supplemental cuts from advance salvage, salvage on clear cuts, and prelogging and relogging were calculated.

9. Then this formula was applied: total annual cut = indicated harvest cut (final thinning yields + salvage of fire and catastrophic losses + harvest clear cuts) + supplemental cut (thinning yields + advance salvage + salvage on clear cuts + yields from prelogging and relogging).

# Summary Projections, 2000-2070

In each district, prospective cuts for one rotation beyond the year 2000 were estimated by decade, using an area-volume check based on the year 2000 inventory for each ownership. Type-site classes were averaged within ownership

classes. Average rotations were applied, derived from those in table 44 according to area of each type-site.

The guiding principle was to sustain the cutting rate of the 1990's throughout the rotation within districts and ownership classes. Occasionally, some reductions were necessary when age-class shortages appeared. Within districts these were mostly compensated for by increased cuts in other ownerships.

Cutting ages were not allowed to drop more than 10 years below rotation except for small private owners, where cutting sometimes was reduced as much as 15 years below rotation age. In all ownerships, the time required to cover the entire area once was not allowed to fall more than 5 years below rotation age.

The trend toward increased thinning was continued beyond 2000. A determination was made of 1990 thinning yield as a percent of clear-cut yield for each ownership class. These percentage figures were increased an additional 5 percent each decade to a maximum of 40 percent of the yield from clear cutting. At the highest level, thinnings constituted 28.6 percent of the total cut.

Due to the complete conversion of old growth in the first decades after 2000, extra yields from prelogging, relogging, and salvage of mortality, other than that realized through thinnings, were assumed to become negligible and were not counted after the year 2000.

Table 52. — Prospective annual output of timber in the Puget Sound district if present trends continue, by decade, ownership class, and source of output, 1960-2000

(In million board feet)

| Source of output | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DECADE OF 1960's** | | | | | | | | | |
| Reduction of inventory | 23 | 35 | 64 | 122 | 437 | [1]0 | 50 | 487 | 609 |
| Replaced by growth | 1,090 | 108 | 413 | 1,611 | 270 | 35 | 224 | 529 | 2,140 |
| Salvage | 77 | 9 | 13 | 99 | 72 | 2 | 16 | 90 | 189 |
| All | 1,190 | 152 | 490 | 1,832 | 779 | 37 | 290 | 1,106 | 2,938 |
| **DECADE OF 1970's** | | | | | | | | | |
| Reduction of inventory | 77 | [1]0 | 149 | 226 | 458 | [1]0 | [1]0 | 458 | 685 |
| Replaced by growth | 1,100 | 137 | 312 | 1,549 | 297 | 22 | 392 | 711 | 2,260 |
| Salvage | 74 | 7 | -- | 81 | 96 | 1 | 20 | 117 | 197 |
| All | 1,251 | 144 | 461 | 1,856 | 851 | 23 | 412 | 1,286 | 3,142 |
| **DECADE OF 1980's** | | | | | | | | | |
| Reduction of inventory | [1]0 | 19 | 193 | 212 | 443 | 11 | [1]0 | 454 | 666 |
| Replaced by growth | 1,262 | 131 | 219 | 1,612 | 289 | 35 | 408 | 732 | 2,344 |
| Salvage | 71 | 3 | [2] | 74 | 110 | 2 | 26 | 138 | 212 |
| All | 1,333 | 153 | 412 | 1,898 | 842 | 48 | 434 | 1,324 | 3,222 |
| **DECADE OF 1990's** | | | | | | | | | |
| Reduction of inventory | 165 | 28 | 155 | 348 | 489 | 4 | 38 | 531 | 879 |
| Replaced by growth | 1,263 | 136 | 167 | 1,566 | 264 | 39 | 376 | 679 | 2,245 |
| Salvage | 61 | 1 | 1 | 63 | 102 | 1 | 25 | 128 | 191 |
| All | 1,489 | 165 | 323 | 1,977 | 855 | 44 | 439 | 1,338 | 3,315 |

[1] Cut does not exceed growth and hence does not reduce inventory.
[2] Less than ½ million board feet.

Table 53. — Prospective annual output of timber in the Columbia River district if present trends continue, by decade, ownership class, and source of output, 1960-2000

(In million board feet)

| Source of output | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DECADE OF 1960's** | | | | | | | | | |
| Reduction of inventory | 318 | 373 | 921 | 1,612 | 941 | 234 | [1] | 1,175 | 2,787 |
| Replaced by growth | 1,532 | 61 | 461 | 2,054 | 563 | 235 | 281 | 1,079 | 3,133 |
| Salvage | 139 | 22 | 13 | 174 | 124 | 39 | 18 | 181 | 355 |
| All | 1,989 | 456 | 1,395 | 3,840 | 1,628 | 508 | 299 | 2,435 | 6,275 |
| **DECADE OF 1970's** | | | | | | | | | |
| Reduction of inventory | 45 | 233 | 543 | 821 | 727 | 236 | [1] | 963 | 1,784 |
| Replaced by growth | 1,812 | 81 | 384 | 2,277 | 781 | 250 | 299 | 1,330 | 3,607 |
| Salvage | 149 | 7 | [2] | 156 | 153 | 35 | 8 | 196 | 352 |
| All | 2,006 | 321 | 927 | 3,254 | 1,661 | 521 | 307 | 2,489 | 5,743 |
| **DECADE OF 1980's** | | | | | | | | | |
| Reduction of inventory | [1]0 | 169 | 420 | 589 | 786 | 200 | [1]0 | 986 | 1,575 |
| Replaced by growth | 2,004 | 73 | 275 | 2,352 | 726 | 288 | 339 | 1,353 | 3,705 |
| Salvage | 105 | 5 | 1 | 111 | 190 | 35 | 11 | 236 | 347 |
| All | 2,109 | 247 | 696 | 3,052 | 1,702 | 523 | 350 | 2,575 | 5,627 |
| **DECADE OF 1990's** | | | | | | | | | |
| Reduction of inventory | 275 | 25 | 126 | 426 | 618 | 269 | [1]0 | 887 | 1,313 |
| Replaced by growth | 1,951 | 144 | 317 | 2,412 | 933 | 234 | 359 | 1,526 | 3,938 |
| Salvage | 90 | 1 | [2] | 91 | 156 | 28 | 7 | 191 | 282 |
| All | 2,316 | 170 | 443 | 2,929 | 1,707 | 531 | 366 | 2,604 | 5,533 |

[1] Cut does not exceed growth and hence does not reduce inventory.
[2] Less than ½ million board feet.

Table 54. — Prospective annual output of timber in Southwest Oregon if present trends continue, by decade, ownership class, and source of output, 1960-2000

(In million board feet)

| Source of output | Private holdings | | | | Public holdings | | | | All holdings |
|---|---|---|---|---|---|---|---|---|---|
| | Large | Medium | Small | Total | National Forest | Other Federal | Other | Total | |
| **DECADE OF 1960's** | | | | | | | | | |
| Reduction of inventory | 723 | 118 | 389 | 1,230 | 339 | 347 | 54 | 740 | 1,970 |
| Replaced by growth | 463 | 22 | 77 | 562 | 230 | 206 | [1] 0 | 436 | 998 |
| Salvage | 111 | 12 | 2 | 125 | 52 | 72 | 5 | 129 | 254 |
| All | 1,297 | 152 | 468 | 1,917 | 621 | 625 | 59 | 1,305 | 3,222 |
| **DECADE OF 1970's** | | | | | | | | | |
| Reduction of inventory | 487 | 70 | 192 | 749 | 358 | 335 | 18 | 710 | 1,459 |
| Replaced by growth | 427 | 23 | 48 | 498 | 219 | 233 | 37 | 490 | 988 |
| Salvage | 59 | 3 | -- | 62 | 73 | 81 | 5 | 159 | 221 |
| All | 973 | 96 | 240 | 1,309 | 650 | 649 | 60 | 1,359 | 2,668 |
| **DECADE OF 1980's** | | | | | | | | | |
| Reduction of inventory | 92 | 33 | 74 | 199 | 361 | 258 | 35 | 654 | 853 |
| Replaced by growth | 658 | 11 | 49 | 718 | 228 | 321 | 24 | 573 | 1,291 |
| Salvage | 24 | [2] | -- | 24 | 77 | 97 | 5 | 179 | 203 |
| All | 774 | 44 | 123 | 941 | 666 | 676 | 64 | 1,406 | 2,347 |
| **DECADE OF 1990's** | | | | | | | | | |
| Reduction of inventory | 34 | [3] 0 | [3] 0 | 34 | 314 | 355 | 31 | 700 | 734 |
| Replaced by growth | 822 | 40 | 76 | 938 | 293 | 238 | 35 | 566 | 1,504 |
| Salvage | 13 | 1 | -- | 14 | 104 | 78 | 6 | 188 | 202 |
| All | 869 | 41 | 76 | 986 | 711 | 671 | 72 | 1,454 | 2,440 |

[1] Assumed withdrawal of forest land from commercial use causes inventory reduction to exceed timber cut.
[2] Less than ½ million board feet.
[3] Cut does not exceed growth and hence does not reduce inventory.

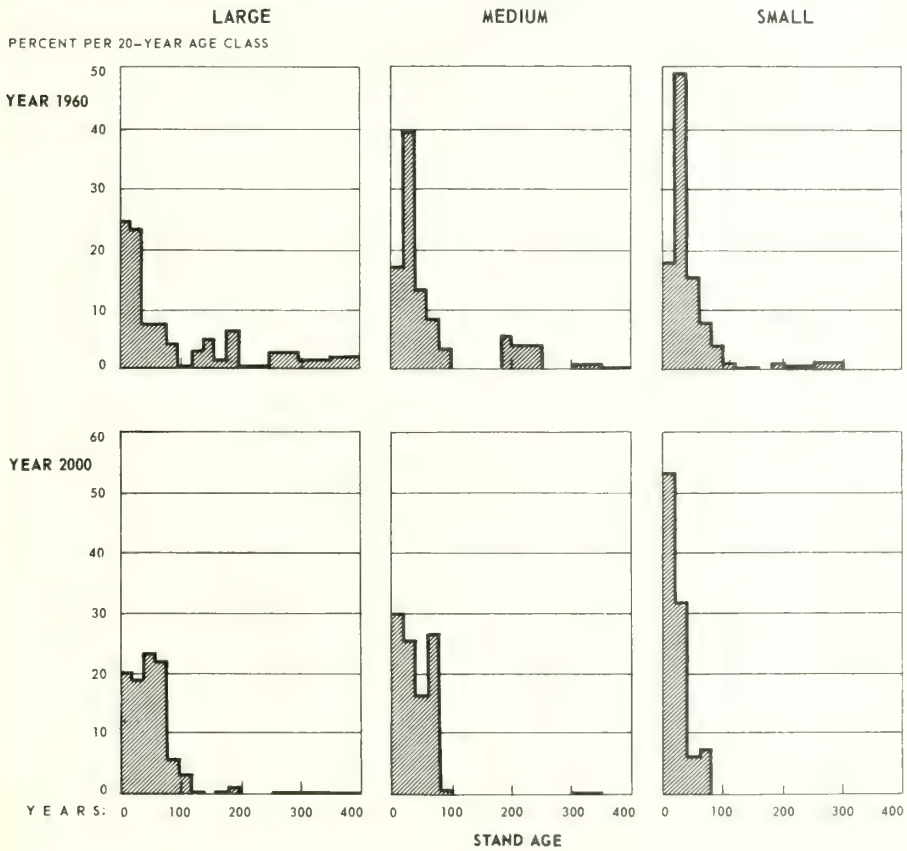


Figure 19.—Distribution of even-aged coniferous commercial forest area by stand-age class for major classes of private ownership, Puget Sound district, 1960 and 2000, if present trends continue.

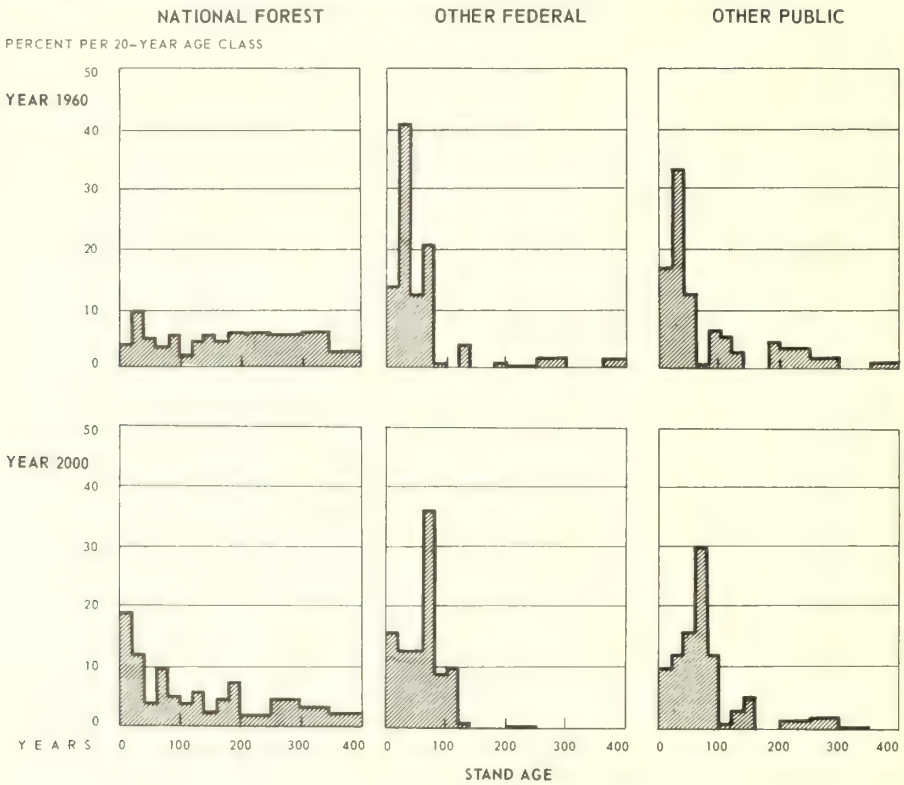


Figure 20.—Distribution of even-aged coniferous commercial forest area by stand-age class for major classes of public ownership, Puget Sound district, 1960 and 2000, if present trends continue.

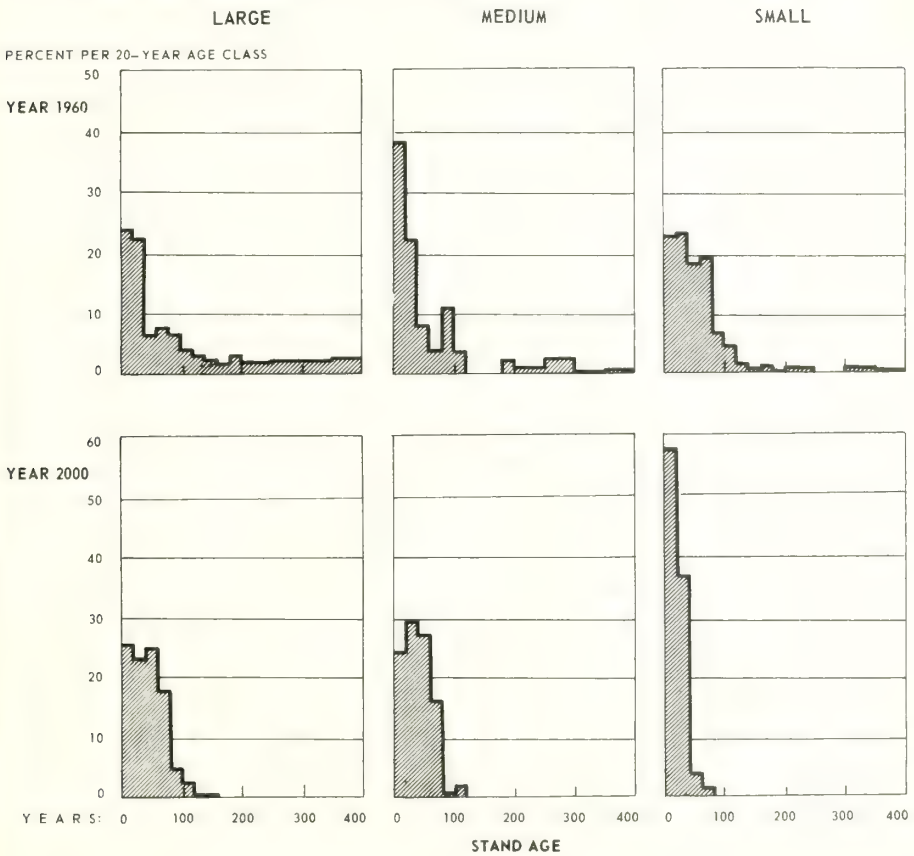


Figure 21.—Distribution of even-aged coniferous commercial forest area by stand-age class for major classes of private ownership, Columbia River district, 1960 and 2000, if present trends continue.

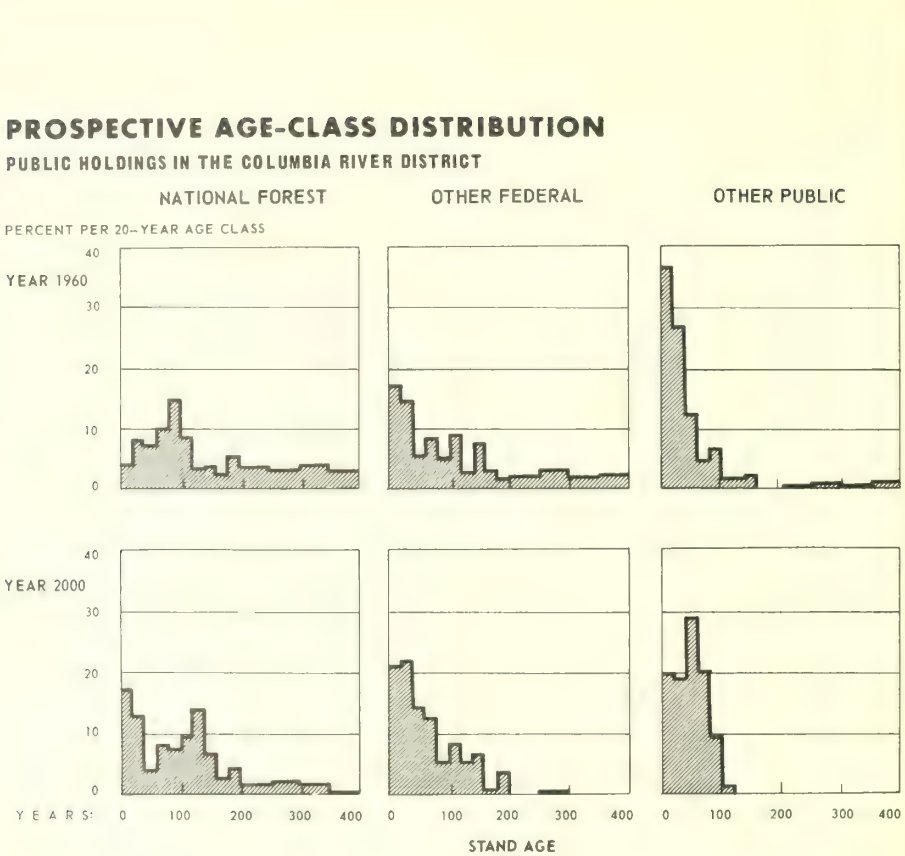


Figure 22.—Distribution of even-aged coniferous commercial forest area by stand-age class for major classes of public ownership, Columbia River district, 1960 and 2000, if present trends continue.

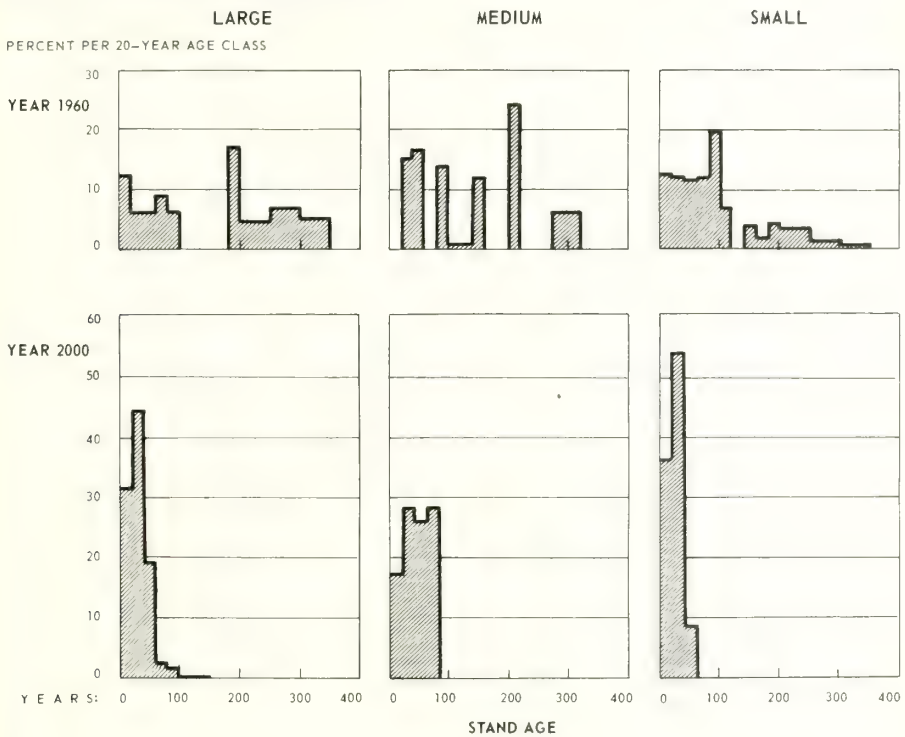


Figure 23.—Distribution of even-aged coniferous commercial forest area by stand-age class for major classes if prviate ownership, Southwest Oregon district, 1960 1960 and 2000, if present trends continue.

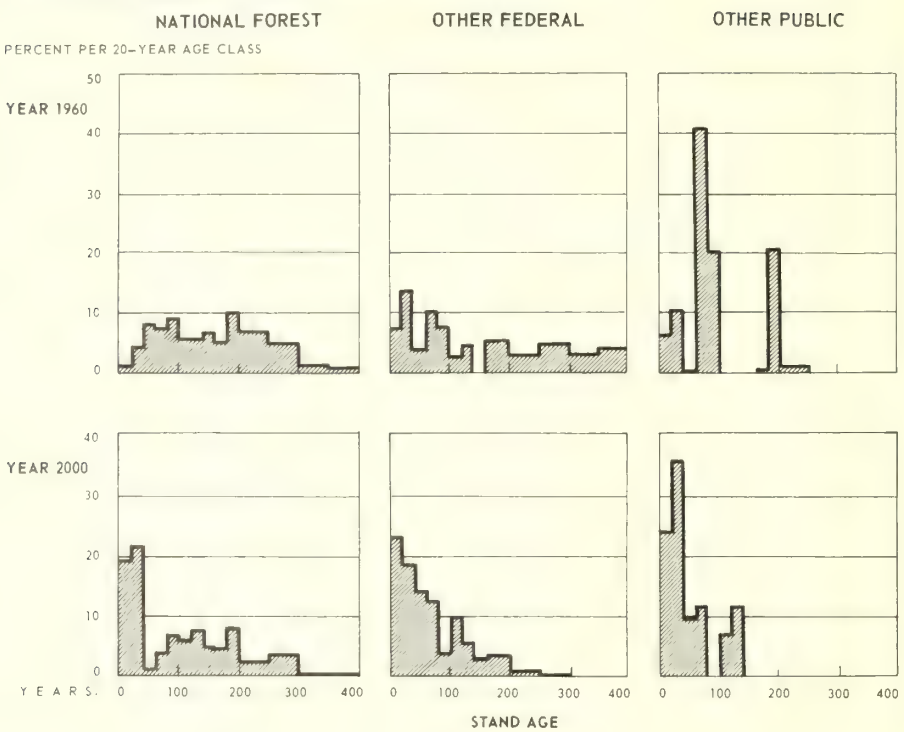


Figure 24.—Distribution of even-aged coniferous commercial forest area by stand-age class for major classes of public ownership, Southwest Oregon district, 1960 and 2000, if present trends continue.

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GPO 985-793

U. S. Forest Service, Pacific Northwest Forest
and Range Experiment Station Division of Forest Economics Research.

1963. Timber trends in western Oregon and western Washington. U. S. Forest Serv. Res. Paper PNW-5, 154 pp., illus.

An economic analysis is made of the timber production potential of the Douglas-fir subregion of western Oregon and western Washington. Projections of cut and growth are applied to the timber inventory of the 1950's to trace future development of the resource under various assumptions concerning trends in forest ownership, protection, cutting programs, and reforestation. The economic model, the projection procedure, and the inventory now and in the future are described in detail.

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# Protecting FOREST TREES and their SEED from Wild Mammals

(A review of the literature)

by M. A. RADWAN

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FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE · FOREST SERVICE

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Research Paper PNW-6

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DECEMBER 1963

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
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FOREST SERVICE

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# INTRODUCTION

An extensive literature points to wild mammals as agents that may seriously reduce the productive capacity of forests and, in many ways, interfere with efforts to grow valuable trees. While this loss of forest values is not a new problem, it has been brought into sharper focus through better identification of the various kinds of mammal-caused injuries and by improved survey techniques. These latter actions have been spurred by the high values now attached to forest products and consequent emphasis on early regeneration of timber stands.

Mammals may attack various parts of the plant at different stages of its development to produce injuries differentiated in type, intensity, and effect on growth and development. Wild mammals may also prefer certain plant species and even certain individuals of a species *(68)*. Limited investigation, however, has not linked animal preference to such tree properties as succulence *(111)* or content of protein *(26)*, vitamin *(171)*, or phosphorus *(59)*.

Wild mammals which cause damage to trees and create problems for the forest manager range in size from the tiny shrew to the gigantic elk. A number of wild mammals known to cause damage are listed in the appendix.

Most injury to forest trees comes from animal feeding activities, resulting in seed destruction, cone severing, browsing, clipping, bud nipping, seedling pulling, tree cutting, and debarking. Other injuries, mainly trampling and rubbing, are caused by movements of large animals.[1]

Effective control measures must be devised to combat destructive mammals if adequate forest production is to be achieved. Although progress has been made in recent years toward improving protection measures, the amount of forestry research on wild mammal control is still inadequate.

This paper summarizes some published research on the control of wild mammal damage to forest trees.[2]

# MEANS OF PROTECTION

## Reduction of Mammal Populations

### Biological

*Predators.*—Protecting and introducing predators has been suggested by some investigators *(91, 146)* as a means of reducing rodent densities and damage to seeds and seedlings. Howard *(78)*, however, pointed out that predators are of little significance in regulating rodent densities. He believes that rodents control predator populations, rather than the reverse.

*Diseases.*—Introducing a disease among problem mammals as a method of control has been hesitantly considered because of the conflict in general acceptance of a given animal as a pest, coupled with the possibility that introduced diseases may spread to game animals. The method,

[1] Reported types of wild mammal damage to forest trees, motivation therefor, the animal responsible, and references to literature are contained in the appendix.

[2] The survey of literature was completed in December 1961.

however, was successfully utilized in Australia *(67, 125)* by releasing the myxoma virus, the causative agent of a disease called myxomatosis, to control the European rabbit *(Oryctolagus cuniculus)*.

*Chemosterilants.*—In recent years, entomologists and bird-control specialists have recognized the value of chemosterilants. Investigations with chemicals that induce sterility in insects and birds are now in progress. Toxic agents that would reduce the population are mixed with chemosterilants that would destroy the reproductive ability of the survivors. This principle has never been used in forestry in the control of wild mammals, and its evaluation would be highly desirable.

## Trapping and Shooting

Trapping or shooting can be used to reduce the population of large mammals, but these methods are impractical for the control of small rodents in forests *(91, 146)*. Hunting and trapping are both used to control bear in western Washington *(102)*, and hunting to control porcupines is practiced on high-damage areas in the ponderosa pine region. The value of legal hunting of deer and elk has also been generally recognized. Many foresters recommend its intensification *(2)*, especially on young plantations *(91)*.

## Poison Baits

Seeds, fruits, or roots formulated into poison baits with strychnine, zinc phosphide, compound 1080,[3] warfarin,[4] thallous sulfate, tetramethylenedisulphotetramine (tetramine),[5] sodium arsenite, or some other rodenticide have proven useful or have shown promise of becoming useful as a practical means of controlling some forest rodents. Investigators have recommended various formulations of poison baits to control meadow mouse *(81)*, wood rat *(76, 115)*, mountain beaver *(135)*, pocket gopher *(45)*, hare *(14)*, and porcupine *(47)*.

Much of the literature on the subject deals with attempts to control seed-eating mammals. Spencer and Kverno *(151)* reported some success with tetramine. In the Douglas-fir region, the two most commonly used poisons are compound 1080 and thallous sulfate applied to wheat or hulled sunflower seed. However, this treatment is not recommended for seeds with intact, inedible hulls because rodents usually cut through poisoned hulls and eat seed contents without being appreciably poisoned.

Compound 1080 gave good initial rodent control when used alone *(52,72,116,161)* or in combination with thallous sulfate *(11)*, but the hazard of secondary poisoning from this compound, compared with that from thallous sulfate, limits its use. Baiting with seed treated with thallous sulfate controlled seed-eating rodents sufficiently to produce satisfactory stocking in both natural *(88)* and artificial *(138)* seeding programs. This method, however, gives only very short periods of control because of rapid reinfestation from untreated areas *(146)*. With current poison bait control methods, rebaiting is often practiced unless buffer strips are included in the initial baiting operation *(11, 72)*.

[3] Sodium fluoroacetate.

[4] 3-(alpha-acetonylbenzyl)-4-hydroxycoumarin.

[5] 2,6-dithia-1,3,5,7-tetrazatricyclo (3.3.1.1.$^{3,7}$) decane-2,2,6,6-tetraoxide. See Appendix for additional information.

## Contact and Systemic Poisons

In recent years, the trend in protecting seed and seedlings from wild mammals has been toward the use of poisonous and repellent chemicals applied to the tree or seed. Poisonous chemicals are of two general types: "contact," those which remain on the surface of treated plants, and "systemic," those which are absorbed and translocated by the plant. Contact poisons do not provide protection to new shoots produced after the plant has been treated. A systemic poison, on the other hand, should be effective on the whole plant, including all new growth produced for some time after treatment.

***Tetramine.***—In 1951, the Denver Wildlife Research Laboratory introduced tetramine for treating coniferous seed. Experiments showed the chemical to be nonphytotoxic, stable *(94)*, and very sparingly soluble. In laboratory tests, treatment of seed with this highly toxic chemical was found to extend protection from rodents to newly formed seedlings with no harmful effects to form or growth rate *(150, 151)*. First field trials on seed treated with a 1-percent solution of tetramine in acetone were effective in controlling rodents, protecting tree seed, and improving the stocking of areas seeded with Douglas-fir *(50, 73, 74, 142)* or ponderosa pine *(63, 151)*. The tetramine-acetone treatment, however, presented many difficulties. Even after modification *(152)*, it continued to reduce germination *(50, 73, 96, 142, 151)* and cause seedling mortality *(142)*. Attempts to reduce the loss in germination, which was thought to be caused mainly by the acetone *(151)*, led to coating seeds with an adhesive containing tetramine. Although the detrimental effect on germination persisted *(44, 50, 130)*, satisfactory stocking of Douglas-fir *(44, 50, 96)* and ponderosa pine *(63, 130)* was obtained.

Tetramine has been suggested as a seedling treatment for decimating hares *(94)* and under certain conditions may be superior to endrin in protecting seed *(44)*. Although some of the properties of tetramine have been determined *(64, 164)*, we have no information on toxicity and effect on metabolism, degree of storage, and excretion of the compound in big-game animals. The extreme toxicity of tetramine to man and wildlife and the hazard that may be created by its use make determination of its effect and its behavior in animals a prerequisite to devising a safe control method for treating seedlings in the field. The hazard question also emphasizes the necessity for additional research in connection with evaluating proposals *(94)* for establishing toxic feeding stations where a buried reservoir of the chemical would be available to the seedlings. Whether this tetramine would be available to other vegetation (e.g., berries, salal, grass, etc.) and whether this would constitute a hazard is still unknown. Determination of leachability, distribution, and stability of tetramine in the soil and the relative absorption, translocation, and degradation of the chemical by different plant species would certainly be helpful in clarifying this point *(124)*. Similar studies would be required in evaluating the proposal that a few trees treated with tetramine in the nursery be included in new plantations *(94)*.

To establish a safe and effective nursery practice, the fate of tetramine in nursery soil must be determined. Knowledge of the behavior of the chemical inside the plant is also necessary to explain the reaction of animals to the treated seedlings in the field. Additional research should be aimed at counteracting the undesirable effects of acetone or discovering a nontoxic solvent. In addition, reevaluation of the chemical must depend on a careful comparison with endrin, such as effect on seed embryos, ease of impregnating seed, and performance of treated seed and newly emerged seedlings in the field.

*Endrin.*—In spite of the relatively successful use of tetramine, the chemical never became commercially available *(149)*, and it was necessary to find another protective agent to replace it in seed treatments. For this purpose, the U.S. Fish and Wildlife Service *(163)* recommended endrin,[6] a nonphytotoxic, commercially available insecticide. This was used in a seed-coating formulation containing an adhesive, the fungicide "thiram"[7] and aluminum powder *(149)*.

The formulation was somewhat effective in protecting coniferous seed from destruction by some rodents *(42, 44, 75, 96, 133)* but was ineffective against ground squirrel populations *(148)*. It also inhibited seed germination *(44)* and, while this may have been due to thiram *(96, 143, 149)*, the adhesive or endrin itself may have contributed to the adverse effect.

Tetramine and endrin coating treatments were also used in attempts to protect natural seed from rodent destruction by first exposing the rodents to artificially sown, treated seed of the same species. This method, however, proved ineffective because the rodents apparently avoided the treated seed *(43, 96)*.

Endrin has also been used in attempts to protect seedlings from damage. Burns *(28)* sprayed 35 different toxic formulations on loblolly pine *(Pinus taeda* L. *)* seedlings and found that endrin was the most effective. Meadow mice were controlled in Germany by spraying grasses and other vegetation with 0.01-percent endrin emulsion *(92)*, and satisfactory *Microtus* control was obtained in England *(71)*.

Since its introduction in 1956, the endrin formulation has not been materially changed, and effects of its components on seed and seedlings are not known. Until a repellent compound or a more effective toxicant with lower toxicity to humans and beneficial wildlife is discovered, the endrin treatment requires more investigation, particularly in connection with effects of its components on seed viability and survival of seedlings from treated seed. Development of an impregnating technique *(93)* is also needed—provided endrin proves nontoxic to seed embryos *(124)*. Such a technique would increase effectiveness of the treatment and may prove useful in cases where the coating treatment usually fails.

*Strychnine.*—Many toxic chemicals have been applied to seedlings and even to the ground vegetation to reduce hare and mouse damage to small trees. Use of such chemicals, however, will always be a calculated risk with respect to the safety of beneficial wildlife and domestic livestock.

Strychnine was one of the first toxicants so used. The U.S. Forest Service and other agencies used planting stock sprayed with adhesives containing strychnine, but reports on effectiveness of the spray were conflicting and inconclusive *(91, 169)*.

*Toxaphene.*—Good control of meadow mice was obtained in Germany by spraying grasses and other surface vegetation with 0.05-percent toxaphene emulsions.[8] Painting individual plant stems with toxaphene gave protection against both mice and rabbits and was not harmful to deer *(107)*. Satisfactory protection of young seedlings and high levels of mouse *(Microtus)* control were also obtained in preliminary experiments in England *(71)*.

[6] 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethanonapthalene. See Appendix for further information.

[7] Tetramethylthiuram disulfide.

[8] Chlorinated camphene (67 to 69 percent chlorine).

***Duration of protection.***—Strychnine, endrin, and toxaphene are believed to be contact toxicants. Apparently they are not absorbed and translocated by the plant and thus do not provide protection to new shoots produced after the seedling has been treated. Protection is confined to the treated parts and probably lasts as long as the toxicant is present in sufficient concentration.

Long-term protection, on the other hand, might be obtained with systemic toxicants capable of being translocated into the new growth either from root or foliage applications. Kverno *(94)* found that a single soil treatment with tetramine produced toxic foliage for 4 years. He hypothesized that toxic plant feeding stations within deer-proof enclosures could be used for reductional control of hares. He also suggested treating a small proportion of the seedlings in a plantation, sufficient for controlling hares but at levels low enough not to endanger deer. The practical value of these ideas has not been demonstrated although work is now underway to evaluate them *(95)*. The future of any tetramine treatment as well as other systemic toxicants will depend largely on success in developing safer and more economical methods of use.

## Manipulation and Exclusion of Mammals

### Cultural

***Improved seeding, planting, and stand-improvement techniques.***—There is always a place for intelligent application of cultural practices as a means of alleviating mammal damage. Good ground preparation, covering the seed with mineral soil, and sowing during periods of low rodent population would reduce seed loss to rodents *(146)*. Injury by rabbits and hares could be minimized where feasible by using large seedlings of less palatable but fast-growing species *(9, 165)*. Clean cultivation and use of resistant seedlings would tend to lessen meadow mouse damage *(29, 81)*. Tree pruning might be helpful in reducing bear damage *(57)* and, when used in combination with thinning, could inhibit wood rat housebuilding activities *(76)*.

***Supplementary feeding.***—Lack of food, a main cause of excessive browsing and clipping, would be relieved by improving existing range conditions and by creating additional foods. Adams *(6)* and Roy *(131)* assumed that maintaining broad-leaved browse species would protect conifers from deer browsing. Rations of felled aspen (*Populus* spp.) were suggested to reduce hare damage *(9)*, and felled spruce provided considerable protection against deer *(80)*. The deliberate planning of deer range as a part of forest management, however, would provide much better protection *(101)*. Bleichert *(22, 23)*, therefore, proposed that from 1 to 3 percent of the forest in small and scattered patches be maintained as pastureland for deer. Planting of such areas to different foodstuffs would promote deer movement and thus reduce time available to debark or browse the trees *(140)*.

***Weed and brush control.***—Brush and weeds can be serious competitors to trees for moisture and nutrients. Moreover, they furnish ideal habitat for some rodents. High populations of meadow mouse are found only on areas supporting a moderate to heavy herbaceous cover *(29, 103)*. Hares, on the other hand, prefer brushy cutover lands *(111)*. Several workers have suggested eliminating or reducing vegetation density, presumably through cultivation, to minimize hare *(9)* and mouse *(29, 103, 118)* damage. Chemical weed and brush control offers many advantages over conventional cultivation methods, but only one account of the use of herbicides has been reported. Experiments at Colorado State University *(33)* have shown that 85 to 95 percent of pocket gophers die off 1 year after ranges are sprayed with 2,4-D.[9] These experiments demonstrate possibilities of the method and should stimulate further research.

[9] 2,4-dichlorophenoxyacetic acid.

*Plant growth regulation.*—Although growth regulators are used extensively in modifying growth and development of agricultural and horticultural plants, very few have been used in forestry. However, it is possible to develop these and other chemicals to achieve the same ends on forest tree seeds and seedlings. Several possibilities for animal-damage control appear evident. If seed would germinate sooner and height growth increase faster, seed and seedling would have a better chance of escaping rodents. Stems would be thicker, lateral shoots stronger, and root systems heavier, thereby increasing seedling resistance to damage and decreasing mortality.

## Mechanical

Animal-proof fences to protect trees have been used in American forestry only to a limited extent because of their high cost. In recent years, however, cost of deer-proof fences has been reduced. Grisez *(61)* suggested the use of standing trees for fence support, and Ow *(117)* described a fence of nylon netting which can be tied to trees by nylon ropes.

Screens were used to protect seed spots from rodents as early as 1911 *(120)*. Since that time, screens of different forms have proven beneficial *(52, 144, 109)*. The cheapest and most practical screens, however, are the K-screens (cylinders of hardware cloth with partially closed tops) *(85)* as modified by Roy and Schubert *(132)*. They are not affected by large rodents or weather conditions and need not be removed from seed spots.

In addition to fences and screens, other protective covers and devices have been used with variable success. These include: mulches *(66, 170)*, newspaper pieces *(65)*, beer cans *(82)*, and gelatin capsules *(79)* to protect seed in seed spots from rodents; paper bags *(104)* and plastic strips *(106)* to protect terminal and lateral buds from deer browsing; metal sleeves with projecting prongs to protect trees against deer rubbing *(126)*; and metal bands to prevent squirrels from climbing cone-bearing trees *(153)*.

## Systemic and Contact Repellents

Repellent rather than toxic chemicals are less hazardous to man, domestic livestock, and big-game animals and other forms of beneficial wildlife. An ideal repellent should be nontoxic to mammals. It must also be chemically stable over reasonable periods of time; nonphytotoxic; capable of being translocated into the plant; nondetrimental to soil, mycorrhizal fungi, or form and rate of growth of plants; inexpensive; and safe for man to use. Unfortunately, none of the chemicals that have been tested for repellency qualify as ideal.

There is no truly systemic repellent for treating seed or seedlings at this time. Claims of "repellency" attributed to some systemic chemicals appear to stem from lack of a satisfactory definition of the term. Such definition must be achieved to clear up current misunderstanding of what constitutes repellent properties of a chemical. In the meantime, the search must be continued for a truly systemic repellent through screening and testing programs.

Very little success has been reported with chemicals applied to seed or to the soil covering seed spots to repel rodents. Iodoform, naphthalene, iodine, zinc chloride, borax, quinine, tannic acid, carbolic acid, etc. failed to protect coniferous seed from rodents *(170)*. Shirley *(144)* found that red lead and sulphonated linseed oil applied to seed or to the soil after sowing gave only

slight protection. More recently, Schubert *(139)* reported that red lead, zinc phosphide, and compound 1080 proved ineffective against rodents when applied to sugar pine seed. The need for an effective repellent for seed treatment, therefore, still exists.

Attention has also been given to protecting seedlings and trees from animals through use of contact repellents. Early attempts, confined largely to orchard trees, were not particularly successful *(68)*. It remained for the U. S. Fish and Wildlife Service, in cooperation with other Government agencies and chemical companies, to initiate testing of various chemicals in an attempt to discover and develop repellent chemicals suitable for both forest and orchard trees. Due to these efforts, several chemical compounds, in different formulations, were "discovered" and field tested. Repellent "96a" (suspension of copper carbonate, copper sulfate, and lime sulfur in ethylene dichloride, with asphalt emulsion and a synthetic resin as adhesives) was reported successful in preventing damage to trees by rabbits *(167)*. It soon became apparent, however, that organic compounds, especially those containing sulfur, nitrogen, the halogens, or combinations of these elements, were the most active repellents *(16)*.

ZAC and TMTD[10] were tested for 5 years against hares, meadow mice, and deer. Ten-percent ZAC or TMTD reduced damage by hares to Douglas-fir, white and red pine, black and white spruce, ponderosa pine, some deciduous species *(18, 20, 21, 165)*, and loblolly pine *(27)*. Small-scale studies indicate effectiveness in protecting Douglas-fir seedlings and 6-year-old ponderosa and lodgepole pines against meadow mice *(19, 21)*. Evaluated as deer repellents, effectiveness of ZAC or TMTD varied widely with species of deer, kind and size of test plants, amount of deer pressure, and length of test period *(18)*. Browsing of treated ponderosa pine seedlings by mule deer was reduced by 73 percent in central Oregon, but Douglas-fir seedlings were not protected from black-tailed deer in western Washington *(21)*. Trials against deer with these repellents should be evaluated directly on each site where a deer problem exists.

TMTD and ZAC have similar repellent properties, particularly against hares. Spray formulations, however, afford protection to seedlings for a very short period of time and may cause some burning of the needles. When planting stock in the nursery is sprayed, a certain amount of the spray reaches the soil, and the possibility exists that some ingredient in the formulation may inhibit beneficial microorganisms in the soil unless it is degraded or inactivated by some soil factor. Effects of the ingredients and their stability in nursery soils deserve investigation. It is equally important to determine stability of these compounds on plant surfaces and effects on the life processes of the plant.

A large number of commercial repellents have also been tested in other countries with some success. Examples of these repellents and the countries in which they were developed are: "Wiltex" *(12)*, Sweden; "Waldine I" and "Waldine II" *(128)*, Switzerland; "Spangol V" *(157)*, Denmark; "Regensburger Verbiss-und Schalschutzmittel–RVS" *(122)* and "Picetol F" *(123)*, Germany; and "Herbasan" and "Sinoxyd F" *(70)*, England.

The relative effectiveness of these foreign formulations, compared with the American repellents, is not known. However, all available repellents, American and foreign, are of the contact type which protect only the treated portion of the plant, not new growth. Annual applications are necessary for satisfactory protection until seedlings outgrow the reach of destructive animals. This method of application is obviously inadequate in view of the expense of repeated field application.

[10] See Appendix for formulation and other information.

Actidione[11] was found most effective against Norway rats in food acceptance and barrier tests *(168)*. A 1-percent formulation with 10-percent lacquer and 1-percent accelerator was extremely phytotoxic to Douglas-fir *(17)*. Similar formulations were injurious to hardwoods except when treatment was limited to stem application *(70)*.

A 5-percent formulation of TNB-A in an organic solvent mixed with resins provided excellent protection to hardwood tree species against hares *(18)*. Douglas-fir was also protected, but the chemical proved to be somewhat phytotoxic *(17)*. It was harmful to needles of ponderosa and lodgepole pine but basal treatments were nonphytotoxic and fairly effective in reducing damage to 6-year-old seedlings by meadow mice *(18, 19)*.

Bone tar oil, applied directly to Douglas-fir seedlings or as a spray broadcast over planted areas, failed to reduce deer damage *(99)*. This was as a 1-percent formulation with 10-percent rhoplex AC-33 as adhesive and Tween-20 as a stabilizer.

Nicotine sprays gave satisfactory protection to deciduous trees against rabbits *(68)*. Clipping of Douglas-fir by hares was reduced by application of 4-percent nicotine sulfate in an asphalt emulsion, with Triton X151 and Triton X171 as stabilizer and spreader.

A 10-percent aqueous emulsion of TN 2531 with 10-percent rhoplex AC-33 adhesive reduced clipping damage by hares on Douglas-fir, ponderosa pine, and some hardwood species *(17)*. This repellent must be applied within 12 hours of mixing and for this reason was replaced by TN 2500.

A 10-percent aqueous emulsion of TN 2500 with 15-percent rhoplex AC-33 adhesive increased Douglas-fir mortality, delayed emergence of terminal buds of red and white pine, but was not injurious to balsam fir, black spruce, or hardwood species. In all tests, it provided some protection against hares *(20)*. A 5-percent spray produced no phytotoxic effects, reduced deer browsing on ponderosa pine *(18)*, and gave satisfactory protection to Douglas-fir against hare clipping *(165)*.

A 10-percent aqueous emulsion of TMTM (tetramethylthiuram monosulfide) with 10-percent polyethelene polysulfide or 10-percent rhoplex AC-33 adhesives reduced rabbit damage to Douglas-fir and some hardwood species *(17)*. Testing of this compound was discontinued, however, in favor of formulations of zinc dimethyldithiocarbamate-cyclohexylamine complex and tetramethylthiuram disulfide.

Spraying conifer seedlings with 10-percent Z.I.P. solution reduced deer damage during winter *(30)*. This chemical also gave good protection from rabbits to Douglas-fir and some deciduous trees *(17)*.

## Area Repellents

Enclosing tree plantations with rope or string impregnated with repellent chemicals has been used experimentally to protect trees from mammals. Eygenraam *(49)* used string impregnated with bone tar and obtained protection against deer for about 2 months. More recently, rope treated with

[11] Additional information on actidione and several other chemicals mentioned in this section is given in the appendix.

an animal tar in a commercial product called "Wam" was reported to have given protection against deer for 6 months *(51)*. The approach, however, is not new and other investigators question its effectiveness in controlling mammal damage *(68)*.

## CONCLUSION

Damage to forest trees, seedlings, and seeds by wild mammals is an increasingly serious and, as yet, unsolved problem. Certainly, the economic values involved make it most urgent that we mount an increased research attack.

It is apparent that measures required to achieve control of wild mammal damage to forest values must be of a much more intensive nature than heretofore contemplated. Costs involved in application of mechanical barriers to animals rule out this approach to the problem on the millions of acres of forest land under consideration. Some help can be expected from cultural measures, intensified trapping and shooting of the larger problem animals, and other direct-action methods, but such efforts are feasible only on relatively small areas.

A review of the literature indicates clearly that a promising approach for the eventual control of wild mammal depredations is the improvement of chemical toxicants and repellents. Contact repellents and toxicants are only a stopgap because they protect only current growth. More effective and longer lasting results will require developing and perfecting the use of truly systemic toxicants or repellents.

A number of organizations, both public and private, are now engaged in research to help solve this problem. Screening and testing of chemicals is being done at increasing rates.

Development of new chemicals must be encouraged, aided perhaps by research on vegetation rarely accepted by some mammals. These plants, even though most succulent and probably nutritious, may contain active chemical compounds that make them unattractive to animals. Whether these chemicals are stable and active outside the plant and whether they can be identified and synthesized for use on conifers needs to be explored *(124)*. We also need more information on animal preference for food as a prerequisite to development of control chemicals.

The problem of wild mammal damage to forest values is increasingly serious and complicated in its solution. It can be solved, however, by strengthening the total research effort.

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# APPENDIX

## Supplementary Information on Some Repellent Chemicals

ZAC. Panogen, Inc., Ringwood, Ill.

("Improved Z.I.P."). Zinc dimethyldithiocarbamate-cyclohexylamine complex with rhoplex AC-33.

TMTD--source Arasan 42-S or Arasan SF-X. E. I. DuPont De Nemours & Co., Inc., Wilmington, Del.

Tetramethylthiuram disulfide. Formulation with rhoplex AC-33 adhesive and suitable defoaming, thickening, and dispensing agents obtainable from Selco Supply Co., Eaton, Colo. ("Selco TMTD-Rhoplex Rabbit & Deer Repellent Concentrate "); formulation containing Arasan 42-S and a modified acrylic resin is available from O. E. Linck Co., Inc., Clifton, N. J. ("TAT-GO"); a 20-percent formulation is also available from Pennsalt Chemicals Corp., Tacoma, Wash. ("Penco Thiram Animal Repellent").

ACTIDIONE. The Upjohn Co., Kalamazoo, Mich.

B-(2-(3,5-dimethyl-2-oxocyclohexyl)-2-hydroxyethyl) glutarimide. Antibiotic.

TNB-A. Panogen, Inc., Ringwood, Ill.

("Ringwood Repellent"). Trinitrobenzene-aniline complex.

TN 2531 (proprietary). Panogen, Inc., Ringwood, Ill.

TN 2500 (proprietary). Panogen, Inc., Ringwood, Ill.

Z.I.P. B. F. Goodrich Chemical Co., Cleveland, Ohio.

("Good-Rite Z.I.P."). Zinc dimethyldithiocarbamate-cyclohexylamine complex with polyethelene polysulfide. Weathering properties are inferior to those of ZAC.

## Some Animals Causing Damage to Forest Resources

| Order | Suborder | Genera[1] | Common name |
|---|---|---|---|
| Artiodactyla | Ruminantia | *Cervus* | wapiti (elk) |
| | | *Dama* | deer |
| Carnivora | | *Ursus* | black and brown bear |
| Insectivora | | *Blarina* | short-tailed shrew |
| | | *Scapanus* | western mole |
| | | *Sorex* | long-tailed shrew |
| Lagomorpha | | *Lepus* | hare |
| | | *Sylvilagus* | cottontail and brush rabbits |
| Rodentia | Hystricomorpha | *Erethizon* | porcupine |
| | Myomorpha | *Clethrionomys* | red-backed mouse |
| | | *Microtus* | meadow vole |
| | | *Mus* | house mouse |
| | | *Napaeozapus* | jumping mouse |
| | | *Neotoma* | wood rat |
| | | *Peromyscus* | white-footed mouse |
| | Sciuromorpha | *Ammospermophilus* | antelope squirrel |
| | | *Aplodontia* | mountain beaver |
| | | *Castor* | beaver |
| | | *Eutamias* | western chipmunk |
| | | *Perognathus* | pocket mouse |
| | | *Sciurus* | tree squirrel |
| | | *Tamias* | eastern chipmunk |
| | | *Tamiasciurus* | red squirrel |
| | | *Thomomys* | pocket gopher |

[1] After Hall, E. Raymond, and Kelson, Keith R. The mammals of North America. 2 v. New York: The Ronald Press Co. 1959.

## Summary of Reported Wild Mammal Damage

| | Literature reference |
|---|---|
| **Seed destruction** | |
| Motivation: | |
| Feeding | 9, 62, 111 |
| Animal causing damage: | |
| Antelope squirrel | 145, 146, 162 |
| Chipmunk | 111, 145, 146, 160 |
| Shrew | 62, 83, 111, 112 |
| Red-backed mouse | 4, 5, 62 |
| House mouse | 146 |
| Jumping mouse | 62, 146 |
| Meadow mouse | 4, 88, 146 |
| Pocket mouse | 146 |
| White-footed mouse | 4, 5, 24, 62, 88, 111, 112, 146, 160 |
| Effects of damage: | |
| Prevents or retards regeneration | 24, 111, 129, 146, 162 |
| May limit regeneration to species of low value | 5, 88 |
| **Cone severing** | |
| Motivation: | |
| Feeding | 111 |
| Animal causing damage: | |
| Red squirrel | 8, 153, 160 |
| Effect of damage: | |
| Reduces current and, possibly, future seed crop | 8, 153 |
| **Browsing** | |
| Motivation: | |
| Feeding | 10, 26, 36, 46, 141 |
| Animal causing damage: | |
| Deer | 6, 10, 26, 40, 110, 114, 119, 131, 158 |
| Elk | 55, 119, 141 |
| Effect of damage: | |
| Reduces stocking | 7, 26, 89 |
| Deforms trees | 89, 156, 159 |
| Reduces height growth | 60, 89, 90, 131, 156 |
| Reduces seedling competitive ability | 6 |
| Retards canopy closure | 13 |
| May increase proportion of low-value tree species | 6, 58, 114 |

**Clipping**
Motivation:
Feeding (foliar damage) 9, 68, 81, 91, 98, 111, 165, 166
Burrowing (root damage) 91
Animal causing damage:
Hares and rabbits generally 9, 14, 41, 68, 77, 91, 111, 154, 165
Snowshoe hare 87, 111, 165
Rabbit *(Sylvilagus)* 48, 84
Rabbit *(Oryctolagus)* 100
Mountain beaver 86, 113, 136
Meadow mouse 100
Red squirrel 8, 15, 166
Wood rat 76
Porcupine 98
Pocket gopher 45, 108
Mole 91
Effect of damage:
Produces effects similar to those of browsing 9, 14, 26, 34, 35, 86, 165

**Bud nipping**
Motivation:
Feeding 119, 166
Animal causing damage:
Rabbit 68
Red squirrel 119, 166
Effect of damage:
Reduced growth 119, 166

**Pulling, trampling, and rubbing**
Motivation:
Feeding (pulling) 110
Antler polishing (rubbing) 119
Animal causing damage:
Deer and elk (pulling) 110
(trampling) 26, 110
(rubbing) 91, 113
Effect of damage:
Reduced stocking 26, 91

**Tree cutting**
Motivation:
Feeding 100, 119
Animal causing damage:
Beaver 100, 110
Effect of damage:
Loss of trees 100, 119
Flooding 69, 110

**Bark stripping**
Motivation:
Feeding--
deer and elk 119, 140
mountain beaver 113
red squirrel 119
bear 25, 53, 105, 1, 127, 172
Medication--bear 53
Nesting material--wood rat 115
Other--bear 105
Animal causing damage:
Bear 31, 53, 57, 97, 102, 105, 172
Deer and elk 119
Mountain beaver 100, 113
Red squirrel 119, 121, 155
Wood rat 54, 76, 115
Effect of damage:
Death of mature trees 31, 102
Top kill and deformation 121
Attack by other animals encouraged 57
Entry of decay organisms permitted 172
Storm resistance decreased 13

**Bark gnawing**
Motivation:
Feeding 9, 32, 68, 81, 91, 98, 111, 166
Animal causing damage:
Mountain beaver 136
Mouse *(Microtus)* 29, 32, 81, 100, 103
Pocket gopher 111
Porcupine 37, 38, 98, 134, 147, 3
Rabbit 68, 119
Red squirrel 119
Effect of damage:
Injury of trunk and branch 91, 113
Top kill and deformation 98
Death of both young and mature trees 68, 81, 98
Entry of decay organisms permitted 98
Reduction of seedling growth rate 81

Radwan, M. A.

1963. Protecting forest trees and their seed from wild mammals. (A review of the literature.) U.S. Forest Serv. Res. Paper. PNW-6, 28 pp.

A review of methods used to control wild mammal damage to forest tree seed, seedlings, and trees is presented. References to mammals causing the damage, their motivation, types of damage, and effect on the forest resource are given.

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A13.78:PNW-7

# Procedure for developing a SITE INDEX ESTIMATING SYSTEM from Stem Analysis Data

MAR 6 -

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FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE · FOREST SERVICE

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# Procedure for developing a SITE INDEX ESTIMATING SYSTEM from Stem Analysis Data

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## INTRODUCTION

Site index curves for red alder[1/] were developed from stem analysis data by a procedure which has since been adopted for lodgepole pine in eastern Oregon and for aspen in Alaska. In these three cases, the results have been so encouraging that a detailed description of the procedure seems justified. The red alder data has been used to illustrate the procedure in the description which follows.

## THE DATA

Forty-three red alder trees from 16 locations scattered throughout the red alder stands of western Washington were selected, felled, and cut into sections during 1957 for the site index phase of the red alder yield-table project.

Height above ground and tree age corresponding to this height were determined for each point of cutting on every tree. Measurements recorded for tree number 26 have been listed in table 1 to illustrate the nature of the basic data.

Table 1.--Basic data for tree No. 26

| Tree age | Tree height | Tree age | Tree height |
|---|---|---|---|
| Years | Feet | Years | Feet |
| 2 | 8 | 25 | 63 |
| 3 | 16 | 29 | 68 |
| 5 | 24 | 34 | 73 |
| 8 | 32 | 37 | 78 |
| 12 | 40 | 41 | 83 |
| 15 | 48 | 52 | 88 |
| 18 | 53 | 58 | 93 |
| 22 | 58 | 68 | 96 |

Tree ages at the time of felling varied: 13 trees were less than 50 years, 3 trees were over 80 years, and the others were somewhere between 50 and 80 years.

Each of the 43 trees was dominant at time of cutting and was considered to have been dominant throughout its entire life. Evidence to the contrary would have been cause for rejection.

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1/ Bishop, Daniel M., Johnson, Floyd A., and Staebler, George R. Site curves for red alder. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 162, 7 pp., illus. 1958.

## THE PROCEDURE

### Step 1

Heights of the various cuts were plotted over corresponding ages for each of the 43 trees, and adjacent points were connected by straight lines. Figure 1 illustrates this step for tree number 26.

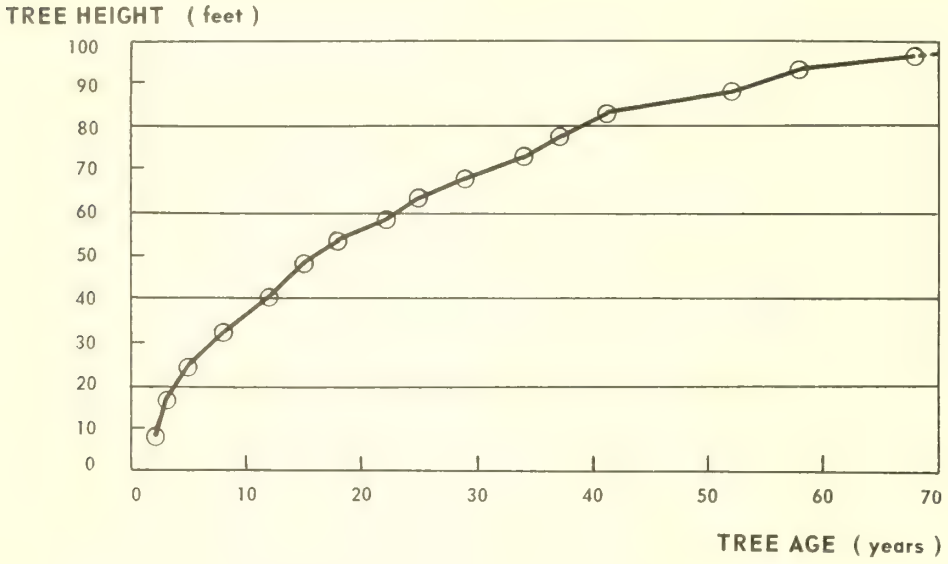


Figure 1.–Height over age for tree No. 26

### Step 2

Heights from the segmented curves constructed in step 1 were listed for each of the following ages: 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, and 70. These heights are shown in table 2 for age 30. All 43 trees were at least 30 years old when cut. The uppermost segment of the curve for each of the 13 trees which were less than 50 years old when cut was extended to intercept age 50. Thus, the table for age 50 corresponding to table 2 also contained 43 trees. These 13 extrapolations covered only a few years at the most and were considered entirely acceptable. Tables for ages 60 and 70 had fewer than 43 trees because extrapolations to ages 60 and 70 were not acceptable for all trees. An example of what was considered to be an acceptable extrapolation may be seen in figure 1 as the broken line extension of the last segment to age 70.

Table 2.--Tree heights at age 30 for 43 trees

| Tree number | Height at age 30 | Tree number | Height at age 30 | Tree number | Height at age 30 | Tree number | Height at age 30 |
|---|---|---|---|---|---|---|---|
| | Feet | | Feet | | Feet | | Feet |
| 1 | 81.5 | 12 | 53.5 | 23 | 94.5 | 34 | 82.5 |
| 2 | 78.5 | 13 | 50.0 | 24 | 80.0 | 35 | 80.0 |
| 3 | 80.0 | 14 | 58.0 | 25 | 72.0 | 36 | 83.0 |
| 4 | 68.5 | 15 | 59.5 | 26 | 69.0 | 37 | 80.0 |
| 5 | 69.5 | 16 | 60.0 | 27 | 66.0 | 38 | 74.5 |
| 6 | 71.0 | 17 | 61.0 | 28 | 68.0 | 39 | 73.0 |
| 7 | 67.0 | 18 | 79.0 | 29 | 63.0 | 40 | 81.5 |
| 8 | 51.0 | 19 | 88.0 | 30 | 57.5 | 41 | 86.0 |
| 9 | 63.5 | 20 | 82.0 | 31 | 57.0 | 42 | 70.0 |
| 10 | 59.0 | 21 | 86.0 | 32 | 47.0 | 43 | 73.0 |
| 11 | 48.5 | 22 | 89.0 | 33 | 53.0 | | |

Step 3

Average height at age 50 as calculated from all trees at a location was arbitrarily called the site index of that location. These site indexes are listed in table 3 for each of the 43 trees. For each of 10 ages (10, 15, 20, 25, 30, 35, 40, 45, 60, and 70), site indexes were then plotted over corresponding heights. This step is illustrated in figure 2 for age 30. Note that site indexes in table 3 were plotted over heights in table 2 to give the scatter diagram in figure 2.

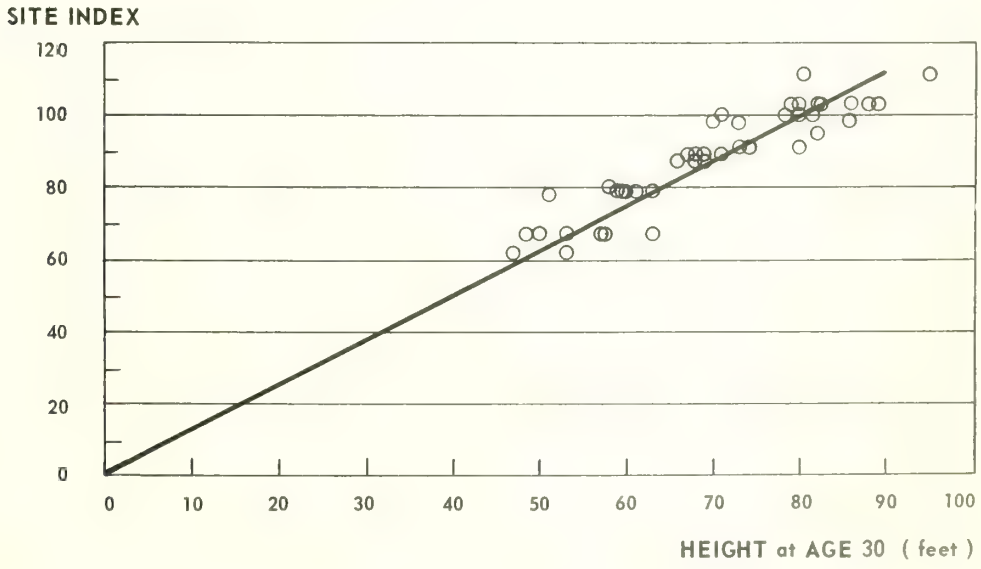


Figure 2.--Scatter diagram. Site index over height at age 30.

Table 3.--Site indexes for 43 trees

| Tree number | Site index | Tree number | Site index | Tree number | Site index | Tree number | Site index |
|---|---|---|---|---|---|---|---|
| 1 | 100.0 | 12 | 67.0 | 23 | 111.0 | 34 | 103.5 |
| 2 | 100.0 | 13 | 67.0 | 24 | 111.0 | 35 | 103.5 |
| 3 | 100.0 | 14 | 80.0 | 25 | 100.0 | 36 | 103.5 |
| 4 | 88.5 | 15 | 78.0 | 26 | 87.5 | 37 | 91.5 |
| 5 | 88.5 | 16 | 78.0 | 27 | 87.5 | 38 | 91.5 |
| 6 | 88.5 | 17 | 78.0 | 28 | 87.5 | 39 | 91.5 |
| 7 | 88.5 | 18 | 103.5 | 29 | 67.5 | 40 | 94.5 |
| 8 | 78.0 | 19 | 103.5 | 30 | 67.5 | 41 | 98.0 |
| 9 | 78.0 | 20 | 103.5 | 31 | 67.5 | 42 | 98.0 |
| 10 | 78.0 | 21 | 103.5 | 32 | 62.0 | 43 | 98.0 |
| 11 | 67.0 | 22 | 103.5 | 33 | 62.0 | | |

Step 4

A linear least squares line was calculated for the relationship of site index to height with a separate line for each of the 10 ages. The line for age 30 is shown in figure 2. There was no indication from these plottings that anything other than a straight line would have been appropriate. Each line was made subject to the condition that site index was zero when height was zero. Subsequent steps in the procedure proved to be intractable unless this condition was imposed. In addition, the condition was not hard to accept. For each of the 10 scatter diagrams, the calculated line was as obviously acceptable as it was in figure 2.

The mathematical expression for each line was:

$$S = bH \quad \text{---------- (1)}$$

where S = site index

H = height at a given age

$$b = \text{regression coefficient} = \frac{\Sigma SH}{\Sigma H^2}$$

Step 5

The 10 regression coefficients from the 10 analyses (table 4) were plotted over age, and a smooth progression of b values resulted (fig. 3).

Table 4.--Regression coefficients for the relationship of site index on height

| Untransformed | | Transformed | |
|---|---|---|---|
| Age (A) | Regression coefficient (b) | x = 1/A-1/50 | y = b-1 |
| 10 | 2.59 | 0.080 | 1.59 |
| 15 | 1.90 | .047 | .90 |
| 20 | 1.54 | .030 | .54 |
| 25 | 1.36 | .020 | .36 |
| 30 | 1.26 | .013 | .26 |
| 35 | 1.16 | .009 | .16 |
| 40 | 1.10 | .005 | .10 |
| 45 | 1.04 | .002 | .04 |
| 60 | .95 | -.003 | -.05 |
| 70 | .90 | -.006 | -.10 |

Step 6

Data in the first two columns of table 4 were transformed as follows to force the condition b = 1.00 when age = 50 (obviously, b must be 1.00 when age is 50 because site index is equal by definition to height at age 50):

$$y = b - 1$$

$$x = 1/A - 1/50$$

where A = age

The transformed values in the last two columns of table 4 were then used to find c for this expression:

$$y = cx$$

$$\text{where } c = \frac{\Sigma yx}{\Sigma x^2}$$

Thus:

$$y = 19.452x$$

and after reconverting y and x:

$$b = 0.611 + 19.452/A \quad \text{----------} \quad (2)$$

This curve is shown in figure 3.

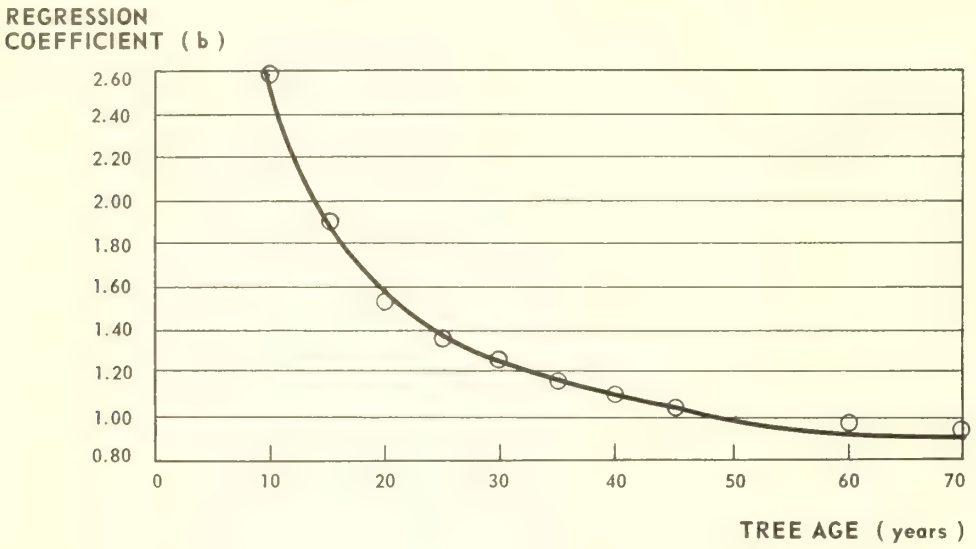


Figure 3.—Regression coefficients for the relationship of site index to height, plotted over age.

Step 7

An equation which generates site index for any combination of age and height resulted when equation 2 was substituted for b in equation 1. Thus:

$$S = (0.611 + 19.452/A)H \quad \text{----------} \quad (3)$$

## DAHMS' MODIFICATION

An evolution of the above procedure is already underway. In developing site curves for lodgepole pine, Dahms[2/] took the height of only the tallest of six trees on a plot at each of several stand ages. Although this left him with only one-sixth the amount of data that would have been available under the procedure described in this report, there is a good chance, at least in his case, that he avoided a serious bias. Except for this one modification, Dahms used the procedure described above.

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2/ Dahms, Walter G. Correction for a possible bias in developing site index curves from sectioned tree data. Jour. Forestry 61: 25-27, illus. 1963.

## DISCUSSION

Equation 3 is not the same as the comparable equation published in "Site Curves for Red Alder"[3/] because a few minor errors were discovered in the original work. Since both equations give almost identical results, these errors were of no practical importance.

When equation 3 is used to develop curves of height over age for each of several site indexes, one curve will be proportional to another in the sense that the ratio of heights for a given age from the two curves will be constant over all ages. This proportionality is caused by the arbitrary restriction on the curves of site index over height (see step 4) which forces them through the zero-zero coordinates. The only justification for the proportionality is the empirical evidence (see fig. 2) which suggests that the restriction is reasonable.

Site index for an individual tree should stay constant over all ages. Thus, if equation 3 were to be applied to the basic data from a single tree, there should be no evidence of a trend when estimated site index is plotted over age. This was done for each of the 43 trees and the results for tree number 26 (see table 1) are shown in figure 4.

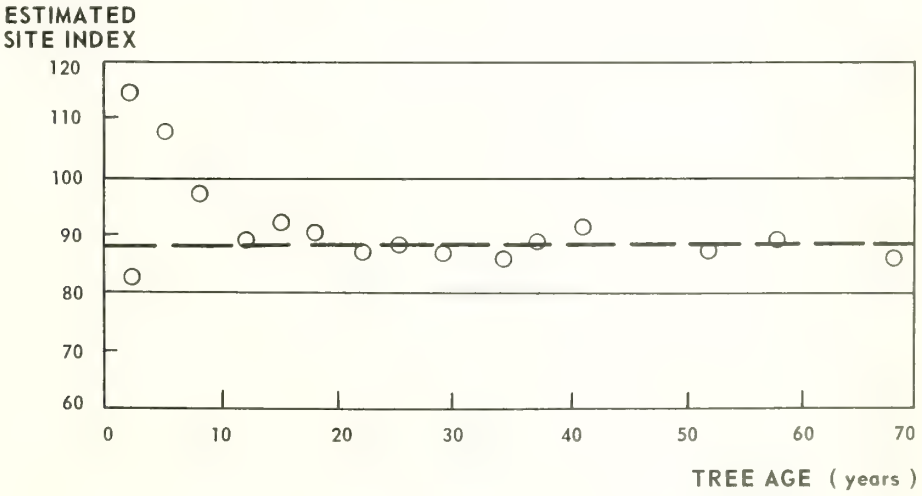


Figure 4.–Estimated site index plotted over age for tree No. 26.

Estimated site index was found from these plottings to be very erratic when age was less than 10 years. Above 10 years, 17 trees gave no evidence indicating a trend of estimated site index on age (tree 26 was one of these 17). A positive trend was apparent on 15 trees, and a negative trend was apparent on the remaining 11 trees. Perhaps this can be taken to mean that equation 3 is acceptable when age is 10 or greater.

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[3/] See footnote 1.

Differences between estimated and actual site index, as calculated from all measurements on all trees, were plotted over age in figure 5. Here, a negative bias is evident below 10 years, and a lack of bias is evident when age is 10 or greater. Standard deviations of these differences were found to be 16 site index units for age class 10 to 20 years, 8 site index units for age class 20 to 30 years, 5 site index units for age class 30 to 40 years, and 4 site index units for age class 40 to 50 years.

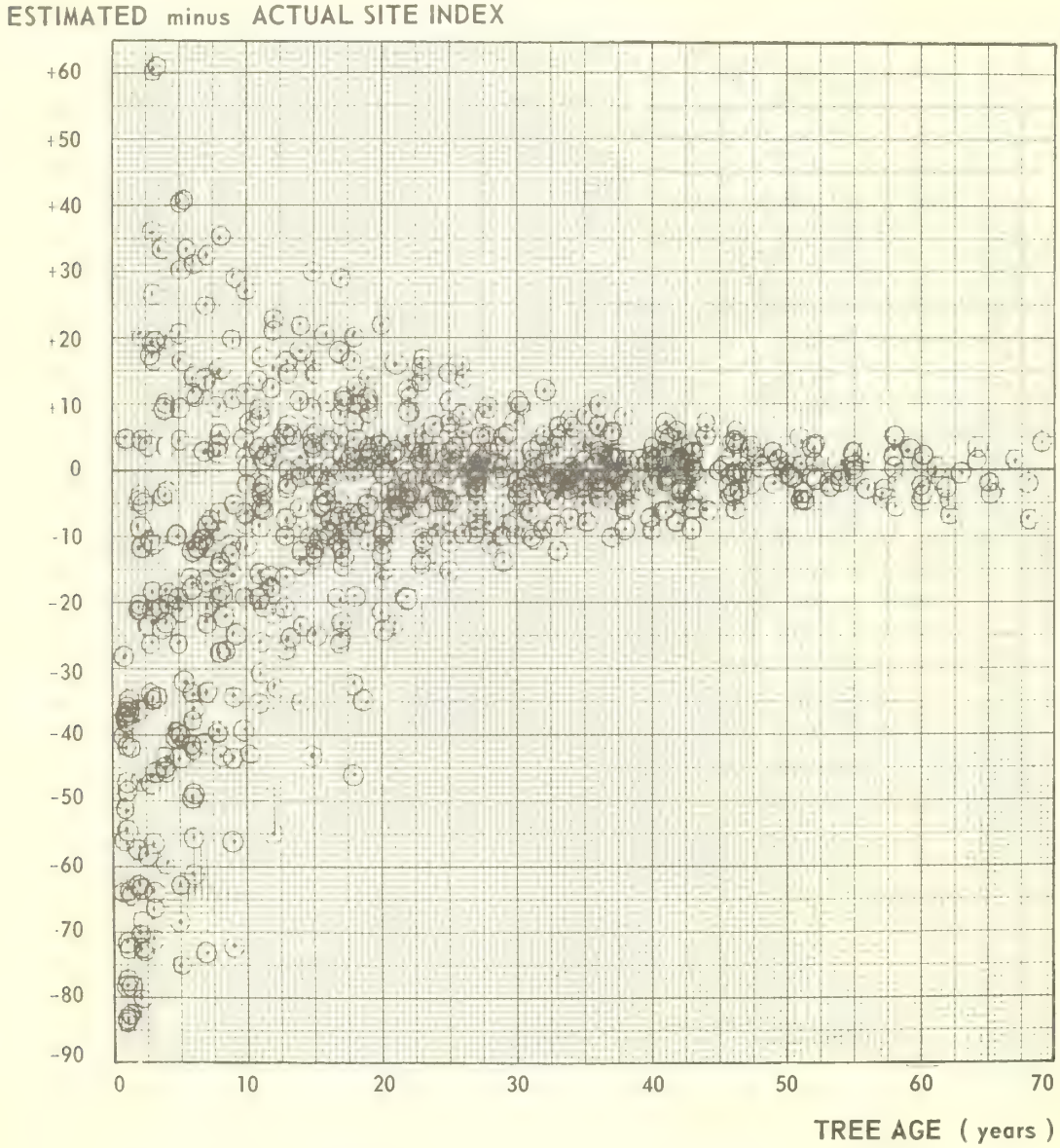


Figure 5.—Differences between estimated and actual site index plotted over tree age ( 43 trees ).

The complete set of red alder data has been made available in table 5 for the benefit of anyone who might wish to experiment further with procedures for developing a site index estimating system.

Table 5.--Basic red alder stem analysis data

| Location | Tree No. | | Heights and ages for 43 red alder trees | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | H | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | | | | | | | | | | |
| | | A | 6 | 8 | 9 | 11 | 16 | 17 | 19 | 26 | 29 | 32 | 38 | 43 | 50 | | | | | | | | | | |
| | 2 | H | 2 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | | | | | | | | | |
| | | A | 1 | 4 | 5 | 8 | 10 | 13 | 16 | 22 | 27 | 31 | 36 | 40 | 46 | 50 | | | | | | | | | |
| | 3 | H | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 102 | | | | | | | | | |
| | | A | 9 | 12 | 15 | 18 | 21 | 23 | 24 | 27 | 30 | 32 | 36 | 41 | 48 | 51 | | | | | | | | | |
| 2 | 4 | H | 2 | 4 | 10 | 20 | 30 | 40 | 50 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 96 | | | | | | | | |
| | | A | 2 | 5 | 6 | 7 | 11 | 15 | 20 | 23 | 25 | 32 | 34 | 37 | 47 | 50 | 58 | | | | | | | | |
| | 5 | H | 10 | 20 | 30 | 40 | 50 | 55 | 60 | 64 | 68 | 74 | 78 | 80 | 84 | 88 | 94 | 98 | | | | | | | |
| | | A | 5 | 6 | 8 | 15 | 17 | 22 | 24 | 25 | 29 | 33 | 35 | 37 | 41 | 46 | 52 | 58 | | | | | | | |
| | 6 | H | 2 | 4 | 10 | 20 | 30 | 40 | 50 | 65 | 70 | 75 | 80 | 85 | 90 | 100 | 105 | 108 | | | | | | | |
| | | A | 2 | 3 | 5 | 6 | 10 | 12 | 13 | 22 | 29 | 34 | 38 | 43 | 60 | 72 | 79 | 83 | | | | | | | |
| | 7 | H | 4 | 10 | 20 | 30 | 40 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 | | | | | | |
| | | A | 3 | 6 | 8 | 12 | 14 | 15 | 18 | 24 | 29 | 31 | 34 | 37 | 51 | 56 | 62 | 64 | 76 | | | | | | |
| 3 | 8 | H | 2 | 6 | 11 | 18 | 24 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 68 | | | | | | | | | |
| | | A | 1 | 4 | 7 | 11 | 13 | 17 | 18 | 20 | 24 | 29 | 33 | 37 | 40 | 43 | | | | | | | | | |
| | 9 | H | 3 | 8 | 16 | 24 | 32 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 74 | | | | | | | | | | |
| | | A | 2 | 3 | 6 | 9 | 11 | 14 | 16 | 18 | 22 | 26 | 32 | 38 | 42 | | | | | | | | | | |
| | 10 | H | 1 | 8 | 16 | 22 | 32 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 71 | | | | | | | | | | |
| | | A | 3 | 4 | 9 | 11 | 14 | 17 | 19 | 22 | 27 | 31 | 36 | 39 | 40 | | | | | | | | | | |
| 4 | 11 | H | 3 | 8 | 16 | 24 | 32 | 40 | 45 | 50 | 55 | 60 | 64 | | | | | | | | | | | | |
| | | A | 2 | 4 | 8 | 10 | 16 | 21 | 27 | 31 | 33 | 43 | 46 | | | | | | | | | | | | |
| | 12 | H | 2 | 8 | 16 | 24 | 32 | 40 | 45 | 50 | 55 | 60 | 65 | 65 | | | | | | | | | | | |
| | | A | 1 | 4 | 8 | 13 | 17 | 21 | 23 | 27 | 31 | 38 | 41 | 42 | | | | | | | | | | | |
| | 13 | H | 1 | 4 | 8 | 16 | 24 | 32 | 40 | 45 | 50 | 55 | 60 | 65 | | | | | | | | | | | |
| | | A | 1 | 5 | 8 | 14 | 17 | 20 | 24 | 28 | 30 | 38 | 43 | 47 | | | | | | | | | | | |
| 5 | 14 | H | 2 | 8 | 24 | 32 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 | 72 | 76 | 80 | | | | | | | | |
| | | A | 1 | 3 | 6 | 11 | 17 | 19 | 23 | 25 | 29 | 31 | 35 | 38 | 40 | 42 | 48 | | | | | | | | |
| 6 | 15 | H | 2 | 8 | 16 | 24 | 32 | 36 | 40 | 48 | 52 | 56 | 64 | 68 | 78 | | | | | | | | | | |
| | | A | 1 | 2 | 4 | 7 | 10 | 11 | 16 | 21 | 24 | 27 | 34 | 37 | 46 | | | | | | | | | | |
| | 16 | H | 2 | 8 | 16 | 24 | 32 | 36 | 40 | 42 | 48 | 52 | 56 | 60 | 64 | 68 | 71 | 79 | | | | | | | |
| | | A | 2 | 3 | 4 | 6 | 11 | 13 | 16 | 18 | 21 | 24 | 26 | 30 | 34 | 38 | 39 | 46 | | | | | | | |
| | 17 | H | 2 | 8 | 16 | 24 | 32 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 | 73 | 79 | | | | | | | | |
| | | A | 1 | 2 | 3 | 5 | 9 | 11 | 13 | 15 | 18 | 22 | 27 | 36 | 39 | 42 | 44 | | | | | | | | |
| 7 | 18 | H | 3 | 8 | 16 | 24 | 32 | 40 | 44 | 48 | 52 | 60 | 64 | 68 | 72 | 76 | 82 | 88 | 92 | 96 | 100 | 104 | 107 | | |
| | | A | 2 | 3 | 6 | 7 | 8 | 10 | 11 | 15 | 16 | 17 | 19 | 21 | 24 | 25 | 32 | 37 | 38 | 43 | 51 | 58 | 62 | | |
| | 19 | H | 3 | 12 | 28 | 40 | 48 | 52 | 56 | 64 | 70 | 80 | 84 | 88 | 92 | 96 | 100 | 104 | 108 | | | | | | |
| | | A | 2 | 3 | 8 | 11 | 13 | 14 | 16 | 17 | 19 | 25 | 29 | 30 | 34 | 35 | 38 | 50 | 55 | | | | | | |
| | 20 | H | 2 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 68 | 72 | 76 | 80 | 84 | 88 | 92 | 96 | 100 | 104 | 108 | 112 | 116 | |
| | | A | 1 | 4 | 6 | 10 | 12 | 14 | 17 | 19 | 21 | 22 | 24 | 27 | 28 | 32 | 34 | 36 | 40 | 41 | 44 | 54 | 61 | 67 | |
| | 21 | H | 2 | 12 | 24 | 32 | 40 | 48 | 52 | 56 | 60 | 68 | 76 | 80 | 84 | 88 | 92 | 96 | 100 | 104 | 108 | | | | |
| | | A | 1 | 2 | 3 | 5 | 7 | 9 | 12 | 15 | 18 | 20 | 22 | 26 | 27 | 33 | 36 | 41 | 45 | 53 | 58 | | | | |
| | 22 | H | 2 | 12 | 24 | 32 | 40 | 48 | 52 | 56 | 66 | 72 | 80 | 84 | 88 | 90 | 96 | 100 | 104 | 108 | 112 | | | | |
| | | A | 1 | 2 | 3 | 5 | 6 | 10 | 11 | 14 | 17 | 20 | 26 | 27 | 29 | 34 | 40 | 46 | 47 | 55 | 65 | | | | |

Table 9.--Basic red alder stem analysis data--Continued

| Location | Tree No. | Heights and ages for 43 red alder trees | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 23 | H | 4 | 12 | 24 | 32 | 40 | 48 | 54 | 60 | 66 | 74 | 80 | 84 | 88 | 92 | 96 | 100 | 104 | 108 | 112 | 116 | | |
| | | A | 2 | 3 | 4 | 6 | 7 | 8 | 10 | 12 | 14 | 15 | 17 | 20 | 23 | 26 | 33 | 34 | 40 | 43 | 46 | 52 | | |
| | 24 | H | 3 | 8 | 20 | 32 | 48 | 52 | 56 | 60 | 64 | 68 | 72 | 76 | 80 | 84 | 88 | 92 | 96 | 100 | 102 | 108 | 112 | 116 |
| | | A | 2 | 5 | 6 | 8 | 13 | 15 | 17 | 18 | 20 | 21 | 22 | 25 | 30 | 32 | 35 | 40 | 42 | 44 | 46 | 51 | 62 | 68 |
| 9 | 25 | H | 3 | 8 | 16 | 24 | 32 | 40 | 48 | 54 | 60 | 64 | 68 | 72 | 76 | 80 | 84 | 88 | 92 | 100 | 104 | 108 | | |
| | | A | 2 | 7 | 9 | 10 | 18 | 19 | 20 | 22 | 23 | 25 | 28 | 30 | 31 | 32 | 37 | 42 | 46 | 50 | 55 | 60 | | |
| 10 | 26 | H | 8 | 16 | 24 | 32 | 40 | 48 | 53 | 58 | 63 | 68 | 73 | 78 | 83 | 88 | 93 | 96 | | | | | | |
| | | A | 2 | 3 | 5 | 8 | 12 | 15 | 18 | 22 | 25 | 29 | 34 | 37 | 41 | 52 | 58 | 68 | | | | | | |
| | 27 | H | 2 | 24 | 32 | 40 | 48 | 53 | 63 | 68 | 73 | 78 | 83 | 88 | 93 | 98 | | | | | | | | |
| | | A | 1 | 8 | 13 | 16 | 20 | 23 | 27 | 34 | 38 | 43 | 47 | 53 | 65 | 73 | | | | | | | | |
| | 28 | H | 2 | 8 | 16 | 24 | 32 | 40 | 48 | 53 | 58 | 63 | 68 | 73 | 78 | 83 | 88 | 93 | 98 | 103 | 107 | | | |
| | | A | 1 | 2 | 7 | 11 | 12 | 15 | 18 | 20 | 21 | 24 | 30 | 34 | 37 | 42 | 46 | 55 | 64 | 69 | 79 | | | |
| 11 | 29 | H | 2 | 8 | 16 | 24 | 32 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 | 72 | | | | | | | | |
| | | A | 1 | 3 | 4 | 5 | 6 | 9 | 13 | 15 | 17 | 20 | 25 | 31 | 41 | 57 | | | | | | | | |
| | 30 | H | 2 | 8 | 16 | 24 | 32 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 | | | | | | | | | |
| | | A | 1 | 3 | 5 | 7 | 11 | 12 | 15 | 16 | 18 | 25 | 38 | 42 | 56 | | | | | | | | | |
| | 31 | H | 2 | 8 | 16 | 24 | 32 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 69 | | | | | | | | | |
| | | A | 1 | 4 | 5 | 10 | 12 | 18 | 20 | 23 | 26 | 28 | 36 | 42 | 62 | | | | | | | | | |
| 12 | 32 | H | 1 | 8 | 16 | 24 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 | 69 | | | | | | | | | |
| | | A | 1 | 4 | 7 | 9 | 15 | 18 | 20 | 23 | 33 | 36 | 41 | 49 | 59 | | | | | | | | | |
| | 33 | H | 1 | 8 | 16 | 24 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 | 63 | | | | | | | | | |
| | | A | 1 | 5 | 7 | 12 | 15 | 16 | 19 | 23 | 25 | 29 | 32 | 37 | 47 | | | | | | | | | |
| 13 | 34 | H | 1 | 8 | 17 | 25 | 33 | 41 | 49 | 57 | 65 | 69 | 75 | 80 | 85 | 88 | 93 | 97 | 101 | 105 | 106 | | | |
| | | A | 1 | 2 | 3 | 5 | 7 | 10 | 11 | 14 | 17 | 18 | 23 | 27 | 33 | 36 | 42 | 46 | 51 | 57 | 60 | | | |
| | 35 | H | 1 | 8 | 17 | 25 | 33 | 41 | 49 | 57 | 65 | 69 | 75 | 80 | 85 | 89 | 93 | 100 | 104 | 108 | | | | |
| | | A | 1 | 2 | 3 | 4 | 7 | 11 | 13 | 15 | 17 | 19 | 25 | 30 | 33 | 36 | 42 | 46 | 49 | 60 | | | | |
| | 36 | H | 1 | 9 | 17 | 25 | 33 | 41 | 49 | 57 | 65 | 70 | 75 | 80 | 85 | 90 | 93 | 100 | 105 | 112 | | | | |
| | | A | 1 | 5 | 6 | 8 | 9 | 11 | 14 | 16 | 19 | 21 | 23 | 27 | 32 | 35 | 42 | 45 | 49 | 60 | | | | |
| 14 | 37 | H | 2 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 76 | 80 | 85 | 90 | 94 | | | | | | | |
| | | A | 1 | 3 | 4 | 5 | 6 | 9 | 12 | 15 | 18 | 23 | 25 | 30 | 36 | 42 | 52 | | | | | | | |
| | 38 | H | 2 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 60 | 64 | 68 | 72 | 76 | 80 | 84 | 88 | 92 | | | | | |
| | | A | 1 | 3 | 4 | 7 | 8 | 11 | 16 | 19 | 20 | 23 | 25 | 28 | 31 | 35 | 39 | 43 | 52 | | | | | |
| | 39 | H | 2 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 68 | 72 | 76 | 80 | 84 | 88 | 94 | | | | | | |
| | | A | 1 | 2 | 5 | 9 | 11 | 13 | 17 | 21 | 24 | 27 | 29 | 33 | 40 | 41 | 46 | 54 | | | | | | |
| 15 | 40 | H | 2 | 8 | 16 | 32 | 40 | 48 | 64 | 72 | 76 | 80 | 84 | 88 | 92 | 96 | 102 | | | | | | | |
| | | A | 1 | 2 | 3 | 8 | 10 | 13 | 19 | 22 | 26 | 28 | 33 | 37 | 43 | 54 | 63 | | | | | | | |
| 16 | 41 | H | 1 | 9 | 17 | 24 | 37 | 49 | 58 | 66 | 74 | 78 | 82 | 86 | 90 | 94 | 98 | | | | | | | |
| | | A | 1 | 2 | 5 | 7 | 8 | 13 | 14 | 17 | 21 | 23 | 26 | 30 | 32 | 36 | 42 | | | | | | | |
| | 42 | H | 1 | 9 | 21 | 33 | 43 | 51 | 59 | 67 | 71 | 75 | 79 | 84 | | | | | | | | | | |
| | | A | 1 | 5 | 6 | 7 | 10 | 16 | 18 | 27 | 31 | 33 | 38 | 43 | | | | | | | | | | |
| | 43 | H | 1 | 9 | 17 | 25 | 33 | 49 | 57 | 62 | 66 | 70 | 74 | 82 | 86 | 90 | 92 | | | | | | | |
| | | A | 1 | 3 | 6 | 8 | 11 | 14 | 19 | 20 | 21 | 24 | 27 | 35 | 37 | 41 | 43 | | | | | | | |

Johnson, Floyd A., and Worthington, Norman P.
1963. Procedure for developing a site index estimating system from stem analysis data. U.S. Forest Serv. Res. Paper PNW-7, 10 pp., illus.

The procedure presented in this report has been applied successfully to three tree species. It is simple, direct, and apparently statistically sound. Perhaps others, faced with the problem of developing site curves from stem data, will find it useful.

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1963. Procedure for developing a site index estimating system from stem analysis data. U.S. Forest Serv. Res. Paper PNW-7, 10 pp., illus.

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# GROSS AND NET YIELD TABLES for LODGEPOLE PINE

by WALTER G. DAHMS

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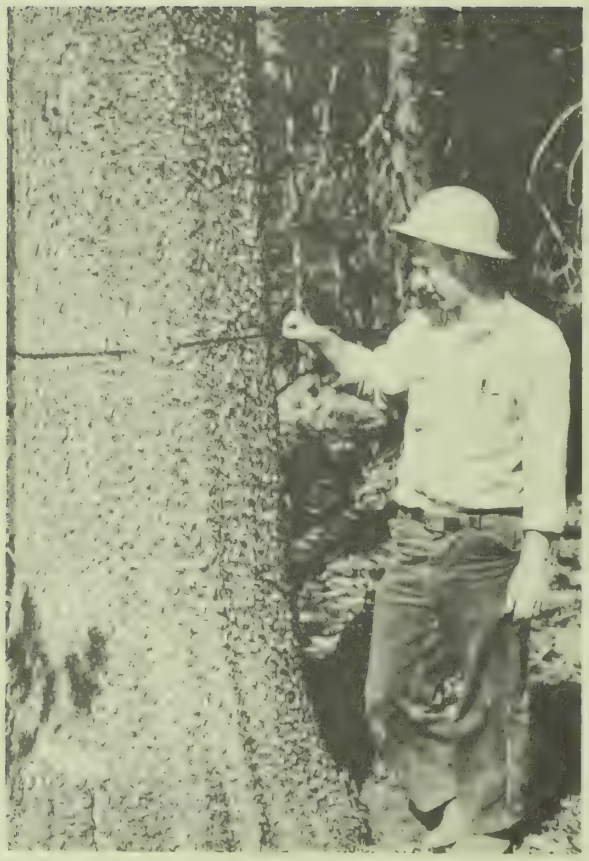

A 25-inch lodgepole pine
growing on the
Winema National Forest

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Research Paper PNW-8

# GROSS AND NET YIELD TABLES for LODGEPOLE PINE

Walter G. Dahms

January 1964

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION

Philip A. Briegleb, Director
Portland, Oregon

U.S. DEPARTMENT OF AGRICULTURE

FOREST SERVICE

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## INTRODUCTION

Gross and net yields of lodgepole pine (Pinus contorta) are presented in this paper for the pumice soil areas of central and south-central Oregon. Both types of yield are given in terms of cubic feet of peeled volume for all stems 1.0 inch d.b.h. and larger. The site index curves upon which the yield figures are based are also presented.

Gross yield represents all of the wood produced. It represents the net yields ordinarily presented in normal yield tables plus the volume of all trees that died.

Gross yield may also represent a potential value that intensive management can approach but never quite reach when the genetically unimproved species is grown on its natural site. As such, it represents a bench mark foresters can use to measure success of their own management practices.

## METHODS

Methods used to obtain gross yield differed from the usual yield table procedures. Gross yield was obtained as a cumulative summary of gross increment.[1/]

Gross basal area and volume increments were estimated on each plot from growth measurements taken on a sample of felled trees and diameter measurements on all trees. Multiple regression methods were used to relate these plot values to the stand values--age, site index, and density.

Volume and basal area found on plots at the time of examination were accepted as net yield and net basal area. Plot values were related to the stand variables--age and site index--by regression methods.

Site index was developed from sectioned trees using methods described by Johnson and Worthington (1963). The original intent was

---

[1/] Increment added by trees that died during the 10-year growth period is actually a part of gross increment but is not included in this case. However, increment thus neglected is so small that it is of little consequence.

to base the index on average height of the 30 tallest trees per acre (6 per 1/5-acre plot). However, to correct a bias caused by shifts in relative height of trees with the passage of time, it became necessary to use height of the single tallest tree per plot as the basis (Dahms, 1963). Subsequent tests showed an estimate of site index, obtained from the single tallest tree per plot, was almost as good as that obtained from the six tallest trees.

## Plot Selection and Distribution

Sampling objectives were twofold: (1) to obtain a good geographical representation of lodgepole pine stands as they occur on pumice soils in central and south-central Oregon and (2) to sample, for each 10-year age span from 30 to 120 years, 10 stands representing the widest possible range in site quality. Plot locations were further limited to pure, even-aged stands with densities high enough to fully occupy the site but not so high that height growth of the tallest trees would be retarded. Tenth-acre plots were used in less than 50-year-old stands and 1/5-acre plots in older stands.

Altogether, 94 plots representing stands varying from 28 to 161 years of age were selected and measured.

## Basic Data

The following basic data were taken on each plot:

1. D.b.h. outside bark of all trees.

2. Total height of the six tallest trees on each plot.

3. D.b.h. inside bark and total height of from 15 to 24 trees per plot at the time of measurement and 10 years earlier. These trees were felled.

4. Total age of all felled dominant and codominant trees.

The following additional data were obtained on some plots:

1. On the first 60 plots, at least three trees per plot were measured for volume table purposes.

2. The tallest six trees were sectioned for site index curve construction purposes on 13 plots.

## Derived Values

The following values were derived for each plot from the basic measurements:

1. Basal area.

2. Cubic volume inside bark.

3. Gross basal-area increment during the past 10 years.

4. Gross cubic-volume increment during the past 10 years.

5. Average stand age.

6. Site index.

7. Crown competition factor.[2/]

---

[2/] Crown competition factor is a measure of stand density described by Krajicek, Brinkman, and Gingrich (1961). Necessary crown-width measurements on free-growing trees were taken by personnel of the Pacific Northwest, Intermountain, and Rocky Mountain Forest and Range Experiment Stations within their own territories. The formula

$$C = \frac{1}{A}\left[0.0192N + 0.0168\Sigma D + 0.0036\Sigma D^2\right]$$

where C = crown competition factor

A = plot area in acres

N = number of trees

D = diameter breast high outside bark

was calculated at the Rocky Mountain Station for the combined data.

## REASONABLENESS OF RESULTS

The two tests used to determine reasonableness of results were:

1. A comparison of gross and net yields obtained in this study and

2. A comparison of gross yield in this study with net yield from the British Columbia yield table (1947).

For site index 50, lodgepole pine net yield represents 68 percent of gross yield at age 80 years and 63 percent at age 120 years. Similarly, net yield from the British Columbia yield table represents 78 and 70 percent of gross yield in the present study at age 80 and 120 years respectively.[3/]

The ratio of net to gross yield found in the present study bears a reasonable relationship to similar ratios for Douglas-fir (Pseudotsuga menziesii), and ponderosa pine (Pinus ponderosa). Net yield for site III Douglas-fir represents 79 and 73 percent of gross yield at ages 80 and 120 years, respectively (Staebler, 1955). Similarly, net yield of

---

[3/] Site index 50 in the present study was estimated to be the equivalent of site index 57 in the British Columbia yield table site index system (average height of dominant and codominant trees at age 80 years). Average height of dominant and codominant trees was estimated from height of the single tallest tree per 1/5-acre plot with the equation:

$$H_a = -1.84 + 0.892H_t$$

where $H_a$ = average height of dominant and codominant trees

$H_t$ = height of tallest tree

Similarly, height of the single tallest tree per 1/5-acre plot can be estimated from the equation:

$$H_t = 2.06 + 1.12H_a$$

ponderosa pine represents 79 and 74 percent of gross yield at ages 80 and 120 years (Meyer, 1938).[4/]

The most obvious reason for the greater difference between net and gross yields in the present study is choice of plots in less than full or normal density.[5/] The result is that net yield drops in direct proportion to density. Gross increment from which gross yield is derived, however, is much less affected.

## APPLICATION

Gross yield figures presented herein provide for at least the following estimates and uses:

1. An estimate of the total wood-producing capacity of lodgepole pine in terms of cubic feet.

2. An opportunity to compare the productive capacity of a given site for lodgepole pine and some other species, provided there is a gross yield table for the other species and both can be found growing on the same site.

3. An estimate of culmination age for gross mean annual increment.

Results obtained with this yield table are heavily dependent upon accurate site index estimates. Reduction of height growth by overdensity is probably the greatest obstacle to obtaining such estimates. Smithers (1956) has shown that height growth of lodgepole pine is substantially reduced by only moderate overdensity. The average density of stands in the present study appears to represent a safe upper density limit for

---

[4/] Gross yield for ponderosa pine was estimated by adding together net yield and mortality as given by Meyer (1938). Meyer called his mortality estimate a minimum one because of his assumption that mortality was limited to the smallest trees in the stand.

[5/] Normal density is used here in the sense of full stocking in the usual normal yield table.

stands where site index is to be measured. This density, expressed in terms of crown competition factor, is:[6/]

$$C = 203.46 - 0.4354Y$$

where Y = age in years

Stands that have been reduced to presently acceptable density standards by heavy mortality should also be avoided.

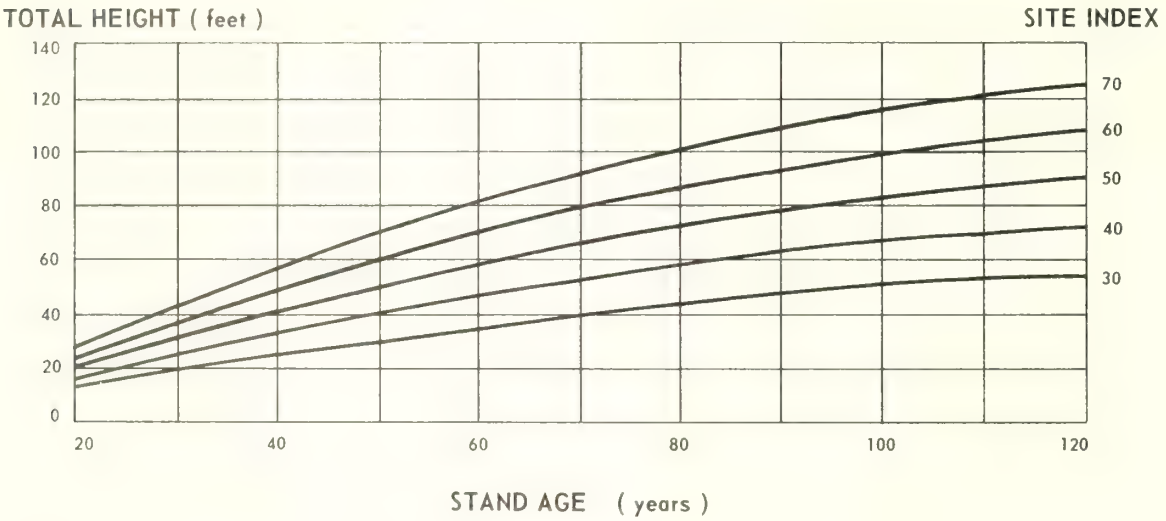


Figure 1--Height of tallest tree per one-fifth acre, by stand age and site index.

[6/] See footnote 2, page 3, and footnote 1, table 3.

Table 1.--Factors for calculating site index[1/]

| Age (the even multiples of 10 years)[2/] | Individual years for each decade | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | Site index factor | | | | | | | | | |
| 20 | 2.488 | 2.353 | 2.237 | 2.128 | 2.028 | 1.942 | 1.862 | 1.792 | 1.724 | 1.661 |
| 30 | 1.605 | 1.553 | 1.504 | 1.458 | 1.416 | 1.376 | 1.339 | 1.304 | 1.271 | 1.241 |
| 40 | 1.211 | 1.183 | 1.157 | 1.133 | 1.109 | 1.087 | 1.066 | 1.045 | 1.027 | 1.008 |
| 50 | 1.000 | .974 | .958 | .943 | .928 | .913 | .900 | .887 | .874 | .862 |
| 60 | .851 | .840 | .829 | .819 | .809 | .799 | .790 | .781 | .773 | .765 |
| 70 | .756 | .748 | .741 | .734 | .727 | .720 | .714 | .707 | .701 | .695 |
| 80 | .690 | .684 | .678 | .673 | .668 | .664 | .659 | .654 | .649 | .645 |
| 90 | .641 | .637 | .633 | .629 | .625 | .622 | .618 | .615 | .612 | .609 |
| 100 | .606 | .602 | .600 | .597 | .595 | .592 | .589 | .587 | .585 | .582 |
| 110 | .580 | .578 | .576 | .574 | .572 | .570 | .569 | .567 | .566 | .564 |

[1/] Factors are reciprocals of denominators for the equation:

$$S = \frac{H_t}{-0.0968 + 0.02679Y - 0.00009309Y^2}$$

where S = site index

[2/] To use, determine breast-high age on one to three dominant trees, including the tallest one. Add 10 years to average breast-high age of trees for which age was counted. Apply to the above table with average calculated total age to get proper site index factor. To obtain site index, multiply this factor by height of the tallest tree on a 1/5-acre plot.

Table 2.--Net yield per acre for lodgepole pine[1/]

| Age (years) | Site index | | | | |
|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 |
| | Cubic feet | | | | |
| 30 | 487 | 843 | 1,198 | 1,553 | 1,909 |
| 40 | 813 | 1,287 | 1,761 | 2,234 | 2,708 |
| 50 | 1,120 | 1,712 | 2,304 | 2,896 | 3,488 |
| 60 | 1,402 | 2,112 | 2,823 | 3,534 | 4,245 |
| 70 | 1,655 | 2,484 | 3,314 | 4,143 | 4,972 |
| 80 | 1,875 | 2,823 | 3,770 | 4,718 | 5,665 |
| 90 | 2,056 | 3,122 | 4,188 | 5,255 | 6,321 |
| 100 | 2,194 | 3,379 | 4,563 | 5,748 | 6,932 |
| 110 | 2,284 | 3,587 | 4,890 | 6,193 | 7,496 |
| 120 | 2,321 | 3,743 | 5,164 | 6,585 | 8,007 |

[1/] Values are for the plots' average stocking, ranging from a crown competition factor of 190 at age 30 to 151 at age 120. Average crown competition factor is expressed by the equation:

$$C = 203.46 - 0.4354Y.$$

It is believed that crown competition factor rather than actual density is correlated with age. Volume per acre for this average density is expressed by the equation:

$$V = 557 - 0.000802Y^3 + 1.1845YS$$

where V = stand volume in cubic feet per acre.

All trees 1.0 inch d.b.h. and larger with stumps and tops included.

Table 3.--Net basal area per acre for lodgepole pine[1/]

| Age (years) | Site index | | | | |
|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 |
| | Square feet | | | | |
| 30 | 101 | 106 | 110 | 114 | 118 |
| 40 | 105 | 111 | 117 | 122 | 128 |
| 50 | 109 | 116 | 123 | 130 | 138 |
| 60 | 112 | 121 | 130 | 138 | 147 |
| 70 | 116 | 126 | 135 | 145 | 155 |
| 80 | 118 | 130 | 141 | 152 | 164 |
| 90 | 120 | 133 | 146 | 159 | 172 |
| 100 | 122 | 136 | 151 | 165 | 179 |
| 110 | 123 | 139 | 154 | 170 | 186 |
| 120 | 124 | 141 | 158 | 175 | 192 |

[1/] Values are for the plots' average stocking, ranging from a crown competition factor of 190 at age 30 to 151 at age 120. Average crown competition factor is expressed by the equation:

$$C = 203.46 - 0.4354Y.$$

It is believed that crown competition factor rather than actual density is correlated with age. Basal area per acre for the average density is expressed by the equation:

$$B = 88.9 + 0.01424YS - 0.000009545Y^3$$

where B = stand basal area in square feet per acre.

All trees 1.0 inch d.b.h. and larger with stumps and tops included.

Table 4.--Mean annual net increment per acre for lodgepole pine[1/]

| Age (years) | Site index | | | | |
|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 |
| | Cubic feet | | | | |
| 30 | 16.2 | 28.1 | 39.9 | 51.1 | 63.6 |
| 40 | 20.3 | 32.2 | 44.0 | 55.9 | 67.7 |
| 50 | 22.4 | 34.2 | 46.1 | 57.9 | 69.8 |
| 60 | 23.4 | 35.2 | 47.1 | 58.9 | 70.8 |
| 70 | 23.6 | 35.5 | 47.3 | 59.2 | 71.0 |
| 80 | 23.4 | 35.3 | 47.1 | 59.0 | 70.8 |
| 90 | 22.8 | 34.7 | 46.5 | 58.4 | 70.2 |
| 100 | 21.9 | 33.8 | 45.6 | 57.5 | 69.3 |
| 110 | 20.8 | 32.6 | 44.4 | 56.3 | 68.1 |
| 120 | 19.3 | 31.2 | 43.0 | 54.9 | 66.7 |

[1/] All trees 1.0 inch d.b.h. and larger with tops and stumps included.

Table 5.--Gross yield per acre for lodgepole pine[1/]

| Age (years) | Site index | | | | |
|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 |
| | Cubic feet | | | | |
| 25 | 319 | 615 | 911 | 1,207 | 1,503 |
| 30 | 588 | 986 | 1,383 | 1,781 | 2,178 |
| 40 | 1,110 | 1,705 | 2,299 | 2,894 | 3,488 |
| 50 | 1,610 | 2,393 | 3,176 | 3,959 | 4,743 |
| 60 | 2,087 | 3,050 | 4,014 | 4,978 | 5,941 |
| 70 | 2,541 | 3,677 | 4,813 | 5,949 | 7,085 |
| 80 | 2,973 | 4,273 | 5,573 | 6,873 | 8,173 |
| 90 | 3,382 | 4,838 | 6,294 | 7,749 | 9,205 |
| 100 | 3,768 | 5,372 | 6,975 | 8,578 | 10,182 |
| 110 | 4,132 | 5,875 | 7,618 | 9,360 | 11,103 |
| 120 | 4,472 | 6,346 | 8,221 | 10,094 | 11,969 |

[1/] Gross yield is net yield to age 25 plus cumulative gross increment obtained by integrating the equation

$$G_v = 1.42 - 0.0439C + 0.01109CS - 0.003366SY$$

where $G_v$ = gross annual volume increment in cubic feet per acre

with respect to age from 25 years to the desired age. The resulting formula for gross per-acre cubic-foot yield is:

$$-570 + 29.61S + \left[-7.52 + 2.256S\right](Y - 25)$$

$$-\left[0.0098 + 0.004103S\right](Y^2 - 625).$$

The gross increment equation accounted for 74 percent of all between-plot variation. Stand density (C) represents the average found on all plots adjusted for age. This average is expressed by the equation

$$C = 203.46 - 0.4354Y.$$

All trees 1.0 inch d.b.h. and larger with tops and stumps included.

Table 6.--Mean annual gross increment per acre for lodgepole pine[1/]

| Age (years) | Site index | | | | |
|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 |
| | Cubic feet | | | | |
| 25 | 12.8 | 24.6 | 36.4 | 48.3 | 60.1 |
| 30 | 19.6 | 32.9 | 46.1 | 59.4 | 72.6 |
| 40 | 27.8 | 42.6 | 57.5 | 72.4 | 87.2 |
| 50 | 32.2 | 47.9 | 63.5 | 79.2 | 94.9 |
| 60 | 34.8 | 50.8 | 66.9 | 83.0 | 99.0 |
| 70 | 36.3 | 52.5 | 68.8 | 85.0 | 101.2 |
| 80 | 37.2 | 53.4 | 69.7 | 85.9 | 102.2 |
| 90 | 37.6 | 53.8 | 69.9 | 86.1 | 102.3 |
| 100 | 37.7 | 53.7 | 69.8 | 85.8 | 101.8 |
| 110 | 37.6 | 53.4 | 69.3 | 85.1 | 100.9 |
| 120 | 37.3 | 52.9 | 68.5 | 84.1 | 99.7 |

[1/] All trees 1.0 inch d.b.h. and larger with tops and stumps included.

Table 7.--Gross annual per-acre basal-area increment for site index 50 lodgepole pine[1/ 2/]

| Age (years) | Basal area | Age (years) | Basal area |
|---|---|---|---|
| | -- Square feet -- | | -- Square feet -- |
| 25 | 5.0 | 75 | 1.6 |
| 35 | 3.6 | 85 | 1.4 |
| 45 | 2.7 | 95 | 1.4 |
| 55 | 2.2 | 105 | 1.3 |
| 65 | 1.8 | 115 | 1.3 |

1/ Values derived from the equation:

$$G_b = 2.83 - \frac{448.06}{Y} + \frac{21,597.7}{Y^2} - \frac{300,693}{Y^3} + \frac{1.32051B}{Y} - 0.01725S$$

where $G_b$ = gross annual basal-area increment in square feet per acre.

This equation accounted for 89 percent of all between-plot variation.

2/ Although the site index term was statistically significant, differences in values for the various site index classes were in such small amounts that there seemed little point in presenting more than the average site quality class values.

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# MERGERS and ECONOMIC CONCENTRATION

## in the Douglas-fir lumber industry

by WALTER J. MEAD

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February 1964

# MERGERS AND ECONOMIC CONCENTRATION IN THE DOUGLAS-FIR LUMBER INDUSTRY

by

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FOREST SERVICE U. S. DEPARTMENT OF AGRICULTURE

# PREFACE

Research for this report was financed under a Cooperative Agreement between the Pacific Northwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, and the University of California. It is part of a long-range study of competition in the Douglas-fir lumber industry being financed by the Bureau of Business and Economic Research, University of California, Los Angeles, California.

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# INTRODUCTION

The strength and condition of the industry which is dependent upon timber from the forests of the Pacific Northwest determines to a great extent the amount of forestry which can be practiced on both public and private lands. Our Nation is dedicated to the principle that our society will benefit most if our economic activities are as free and competitive as practicable. For these reasons the public has become concerned over the recent merger activity in the wood-using industries. The purpose of this report is to objectively present the merger activity that has been going on and to examine the degree of economic concentration that has resulted.

In this study the record of mergers during the 1940's and 1950's was examined. Conclusions are drawn concerning the trend of economic concentration and the present competitive position of the industry at three different levels: timber resource ownership, lumber production, and wholesale lumber distribution.

The Douglas-fir lumber industry is that segment of the United States lumber industry operating in the Douglas-fir subregion. The Douglas-fir subregion includes the 19 counties of western Oregon and the 19 counties of western Washington lying between the crest of the Cascade Range and the Pacific Ocean.

The Douglas-fir subregion, with only 1.8 percent of total U. S. land area and accounting for 4.5 percent of the Nation's forest-land area, contains 37 percent of the remaining softwood sawtimber volume and accounts for 29.2 percent of total U. S. softwood lumber production. The subregion is, therefore, regarded as a major center of the lumber industry for the Nation.

# Mergers and the Trend Of Concentration In the U. S. Economy

The extent of merger activity and the trend of economic concentration in the U. S. economy need to be examined in order to place lumber industry mergers in proper perspective. This brief survey of concentration in the total economy will be concerned, first, with the record of merger activity over a long period of years in order to identify what has been termed "merger movements," and second, with the present degree of economic concentration in the U. S. economy. The present position is, of course, the result not only of mergers but of internal growth as well.

The term "merger" is broadly defined as any combination into a single enterprise of two or more previously independent firms. The merger process most commonly involves a single large firm absorbing partially or totally one or more smaller firms, where the acquiring firm survives and the assets of the acquired firm are absorbed into the surviving organization.

Use of the term "movement" implies a significant increase in merger activity. An outstanding characteristic of American economic development has been successive waves of mergers. Three clearly identifiable merger episodes are commonly referred to in U. S. economic history since 1898: 1898-1902, 1926-30, and 1950 to date.

As an aid in grasping the idea of episodic merger movements, the number of firms disappearing annually through mergers has been plotted in figure 1 for the period 1895 through 1961. The reader should be cautioned against a precise interpretation of trends shown in figure 1. The data are subject to two major limitations: (1) The figure shows only the number of disappearing firms as reported in two business publications, i.e., "Moody's Industrials" and "Standard Corporation Descriptions." The list is, therefore, not a complete record of all mergers but presumably does include the most significant. Because the list is based upon press reports, it is subject to changing standards of reporting. (2) The data are unweighted. Therefore, no distinction is made between the major acquired firm and the minor acquired firm. Each firm is counted as one regardless of its size and importance. These two limitations notwithstanding, figure 1 is useful

Figure 1. — Number of mergers and acquisitions in manufacturing and mining, 1895-1961.

in identifying trends and the so-called merger movements periodically taking place in American economic development.

An impression prevails that the U. S. economy is becoming less competitive and more concentrated with the passage of time. Several research studies have been made testing this commonly accepted hypothesis by analyzing the trend of economic concentration in individual industries. Professor Stigler, in his lectures at the London School of Economics in 1949, reported on the long period from the end of the Civil War to World War II. After classifying industries into those fitting his definition of competitive as opposed to cartelized and monopolized industries, he concluded as follows (Stigler, 1950, p. 54):[1]

[1] Names and dates in parentheses refer to Literature Cited, p. 79.

> **It is my present judgment that competition declined moderately from the Civil War to the end of the 19th century, and thereafter (to 1940) increased moderately. I certainly have not proved this to be the case, but on the other hand there is no obvious evidence for the more popular thesis that competition has been declining steadily for a half century or more.**

In another study more exhaustive than Stigler's, G. Warren Nutter classified productive organization into "effectively monopolistic," "workably competitive," and "governmental." With two different methods employed in estimating 1937 industrial organization, he concluded that with the first method competition increased from 1899 to 1937 and with the second method competition declined. In an attempt to draw an average from his two methods of estimation, he concluded that analysis indicates "a slight decline in the extent of monopoly relative to the economy but a very slight increase relative to the extent of competition" (Nutter, 1951, p. 39).

In a review and analysis of existing competitive studies of the U. S. economy, Professor Adelman was unable to substantiate the hypothesis of increasing concentration. His own interestingly phrased conclusion is as follows (Adelman, 1951, pp. 292-293): "The odds are better than even that there has actually been some decline in concentration. It is a good bet that there has at least been no actual increase; and the odds do seem high against any substantial increase."

While economic research has not substantiated longrun increasing concentration in U. S. industry over the last half century, the periodic merger movements do occur and result in at least temporary increases in industrial concentration. The U. S. Senate Subcommittee on Antitrust and Monopoly recently completed what is probably the most exhaustive statistical analysis of concentration in American industry ever undertaken. This study indicates clearly the effect of the present merger movement in increasing industrial concentration, and also indicates the degree of concentration among the largest firms in the year 1954. As shown in table 1, the 200 largest companies in the U. S. economy accounted in 1947 for 30 percent of all value added by manufacture. The share of the 200 largest firms increased to 37 percent by 1954. Moreover, most of the increase in concentration among the 200 largest firms was, in fact, accounted for by the 50 largest among them. Thus the 50 largest firms in 1947 accounted for 17 percent of all value added by manufacture, increasing to 23 percent by 1954. There are some 4 million companies in business in the United States. The 50 largest firms among them are but one eighty-thousandth, or 0.00125 percent of the total number of firms. This small fraction of total firms in 1954 contributed nearly one-fourth of all value added by manufacture.

Table 1. — Share of total value added by manufacture accounted for by the largest manufacturing companies, 1947 and 1954

| Company ranking in designated year | Percent of value added by manufacture | |
|---|---|---|
| | 1947 | 1954 |
| | Percent | |
| Largest 50 companies | 17 | 23 |
| Largest 100 companies | 23 | 30 |
| Largest 150 companies | 27 | 34 |
| Largest 200 companies | 30 | 37 |

Source: U. S. Congress (1957a, p. 11).

# Mergers in the Douglas-Fir Lumber Industry

The rate of merger activity in the lumber industry increased considerably from 1955 to 1960. Although the lumber and furniture segment of the U. S. economy contributes only 1.3 percent of total national income, it accounted in 1960 for 4 percent of total number of mergers. The combined lumber and furniture and paper and allied products sectors of the economy contribute 2.3 percent of national income. But in 1960 they accounted for 11 percent of total merger activity. A comparison of mergers and acquisitions in several industries within the manufacturing and mining category is shown in table 2.

Table 2. — Mergers and acquisitions of manufacturing, nonmanufacturing, and mining concerns, by industry group of acquiring concern, 1955-61

| Industry group of acquiring concern | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 |
|---|---|---|---|---|---|---|---|
| | Number of mergers | | | | | | |
| Mining | 34 | 35 | 31 | 39 | 29 | 17 | 30 |
| Manufacturing: | | | | | | | |
| Food and kindred products | 54 | 53 | 32 | 36 | 55 | 52 | 62 |
| Tobacco manufactures | 2 | 3 | 4 | 1 | 3 | 3 | 5 |
| Textiles | 30 | 34 | 23 | 16 | 31 | 33 | 33 |
| Apparel | 2 | — | 3 | 3 | 5 | 9 | 10 |
| Lumber and Furniture | 5 | 11 | 5 | 7 | 19 | 25 | 13 |
| Paper and allied products | 18 | 21 | 30 | 26 | 32 | 44 | 27 |
| Printing and publishing | 4 | 8 | 4 | 10 | 15 | 17 | 20 |
| Chemicals | 42 | 53 | 35 | 41 | 62 | 59 | 66 |
| Petroleum and coal products | 7 | 13 | 4 | 9 | 18 | 12 | 21 |
| Rubber products | 4 | 5 | 6 | 4 | 4 | 6 | 9 |
| Leather products | 3 | 5 | 1 | 1 | 5 | 1 | 4 |
| Stone, clay, and glass products | 18 | 13 | 22 | 16 | 26 | 19 | 22 |
| Primary metals | 40 | 23 | 31 | 22 | 37 | 19 | 21 |
| Fabricated metals | 45 | 27 | 46 | 34 | 50 | 41 | 35 |
| Machinery, except electrical | 79 | 79 | 57 | 59 | 76 | 61 | 67 |
| Electrical machinery | 45 | 39 | 40 | 40 | 60 | 92 | 88 |
| Transportation equipment | 39 | 46 | 25 | 38 | 47 | 47 | 38 |
| Professional and scientific instruments | 12 | 14 | 16 | 21 | 30 | 17 | 26 |
| Miscellaneous | 16 | 12 | 23 | 9 | 19 | 28 | 13 |
| Nonmanufacturing | 26 | 43 | 52 | 25 | 33 | 33 | 61 |
| Total | 525 | 537 | 490 | 457 | 656 | 635 | 671 |

Note: Data limited to actions reported by Moody's Investors Service and Standard and Poor's Corporation.

The Federal Trade Commission cautions that the mergers shown are only a partial list and are published only to show the trend. There are many smaller mergers not listed by Moody's or by Standard and Poor's.

Source: Federal Trade Commission news releases.

The shortcomings of simply counting mergers recorded in a 12-month period within several industries are legion. Principal among them is the assumption that all mergers are of the same size. Three mergers involving Georgia-Pacific Corp. as the acquiring firm may exceed in importance four-score small mergers elsewhere. For example, in 1959 Georgia-Pacific acquired Booth-Kelly Lumber Co. for $93 million. Assets included 200,000 acres of timberland, as well as producing plants and an operating railroad. In 1956 the Hammond Lumber Co. was acquired for $75 million, bringing 127,000 acres of timberland into Georgia-Pacific ownership. In 1955 the Coos Bay Lumber Co. was purchased for $70 million, and included among its assets 120,000 acres of timberland (Moody's Investors Service, 1960, pp. 275-276). It is obvious that these three mergers, which involve a total cost of $238 million, may far outweigh in economic significance a large number of smaller mergers. With these reservations in mind, table 2 should be interpreted with caution. The tabulation of mergers shown in table 2 indicates that total merger activity from 1955 through 1961 expanded modestly. The lumber and furniture segment of manufacturing activity and the paper and allied products segment are both among those sectors showing the greatest relative increases in a number of mergers.

## Mergers Among the Present Four Largest Lumber Producing Firms in the Douglas-Fir Subregion, 1940-60

The foregoing has provided a general view of mergers in the lumber industry relative to other U. S. manufacturing industries. For a more detailed examination of mergers in the Douglas-fir sector of the lumber industry, we may examine mergers among the four largest firms producing lumber in the Douglas-fir subregion. The Big Four lumber producers in 1960 were Weyerhaeuser Co., Georgia-Pacific Corp., U. S. Plywood Corp., and Pope & Talbot, Inc. The first three have been involved in extensive merger activity. Pope & Talbot has not been a party to a merger during the 20-year period ending with 1960. In 1961, Pope & Talbot acquired Columbia Veneer Co. At the close of World War II, Georgia-Pacific Corp. (then called the Georgia Hardwood Lumber Co.) was an unimportant factor in the lumber industry. Today, Georgia-Pacific holds second place in regional lumber production.

United States Plywood Corp. acquired full ownership of its first plywood plant as late as 1937 and, by 1940, still had no lumber production in the Douglas-fir subregion. Today, U. S. Plywood is the third largest lumber producer in the subregion, and its mills are supported largely by fee ownership of timber.

Weyerhaeuser Timber Co. (name changed to Weyerhaeuser Co. in 1959) and Pope & Talbot have a long-held leading position in the lumber industry.[2]

In the following list of acquired firms, mergers are listed in which Weyerhaeuser, Georgia-Pacific, and U. S. Plywood are the acquiring firms. The acquired firms in these mergers are not restricted to the Douglas-fir subregion nor to the lumber industry. Judged by the number of such mergers alone, U. S. Plywood has been the most active of the three, having acquired, totally or partially, 28 firms in the 21-year period. Georgia-Pacific made 21 acquisitions beginning in 1944 and at an accelerated rate since 1947. The acquisitions by Georgia-Pacific include some large asset holdings and therefore are of greater significance than the larger number acquired by U. S. Plywood. Weyerhaeuser Co. recorded 18 acquisitions during the 21-year period. The largest was the Kieckhefer-Eddy Companies. Neither firm had operations within the Douglas-fir subregion. The combined purchase price amounted to approximately $200 million, made up of $20,837,448 cash and 5,398,004 shares of Weyerhaeuser Co. stock valued at approximately $180 million (Weyerhaeuser Timber Co., 1957, pp. 4-5).

Following is a list of mergers involving the three largest lumber producing firms as the acquiring firm, Douglas-fir subregion, 1940-60 (sources were Federal Trade Commission and annual reports of acquiring firms):

U. S. Plywood Corp.:

1. Hamilton Veneer Co., Orangeburg, S.C. (1940)
2. Algoma Plywood & Veneer Co., Algoma, Wis. (1940)
3. Tekwood Inc., Lakeport, N. H. (1942)
4. Hay & Co., Ltd., Woodstock, Ontario (1945)
5. Siuslaw Forest Products Co., Mapleton, Oreg. (1945)
6. Kosmos Timber Co. (1946)
7. G. A. Mason Door Co. (1947)
8. One billion feet of timber from Walker family of Minneapolis (1947)
9. National Brick Corp., Long Island City, N.Y. (1953)
10. Siuslaw Forest Products Co. (purchased remainder of minority stock, 1953)

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[2] For an interesting history of the Pope & Talbot operations dating back to 1849, see:

Coman, Edwin T., Jr., and Gibbs, Helen M. Time, tide and timber, a century of Pope & Talbot. 480 pp. Stanford: Stanford University Press. 1949.

Weyerhaeuser Co. history is found in the comprehensive book "Timber and Men: The Weyerhaeuser Story," by Ralph W. Hidy, Frank Ernest Hill, and Allan Nevins. 704 pp. New York: The Macmillan Co. 1963.

Two articles on Weyerhaeuser are also available from previous work:

Anonymous. Bunyan in broadcloth: the house of Weyerhaeuser. Fortune 9(4): 63-65, 170, 173-176, 180, 182. 1934.

Freedgood, Seymour. Weyerhaeuser timber: out of the woods. Fortune 60(1): 93-96. 1959.

For a review of Georgia-Pacific growth and financing, see:

McDonald, John. Georgia-Pacific: it grows big on trees. Fortune 65(5): 111-117. 1962.

11. Capital Plywood, Ltd. (1954)
12. Associated Plywood Mills, Inc., Eugene, Oreg. (plywood) (1954)
13. Shasta Box Co., Douglas City, Calif. (wooden boxes) (1954)
14. Canadian Plywood Ltd. (1955)
15. Muskoka Wood Products Ltd., Ontario (1955)
16. Seattle Export Lumber Co. (1955)
17. Youngs Bay Lumber Co., Inc., Roseburg, Oreg. (1956)
18. North Umpqua Timber Co. (acquired as a wholly owned subsidiary of Youngs Bay Lumber Co.)
19. Barasch Co., N.Y. (vinyl and other plastic materials) (1956)
20. Mutual Plywood Corp., Eureka, Calif. (plywood plant) (1958)
21. National Concrete Corp. (1958)
22. Western Battery Separator Co., San Francisco (wooden handles and plywood veneer) (1959)
23. D. D. Millar & Associates, Ltd., Montreal, Canada (architectural and industrial products; through Weldwood Plywood Ltd.) (1959)
24. Stebco Inc., Vancouver, Wash. (timber) (1959)
25. Walker Logging Co. (1959)
26. Berkeley Plywood Corp., Inc., San Leandro, Calif. (panelized roof system and other plywood building components) (1960)
27. Bohemia Lumber Co., Culp Creek, Oreg. (acquired 50 percent interest) (1960)
28. Panelbild Systems Inc., Seattle, Wash. (1960)

Georgia-Pacific Corp.:

1. Hillgard Lumber Co. (1944)
2. Bellingham Plywood Corp. (1947)
3. Washington Veneer Co. from Weyerhaeuser Timber Co., Olympia, Wash. (1948)
4. General Plywood (partial) (1948)
5. Acme Door Co., Hoquiam, Wash. (1950)
6. C. D. Johnson Lumber Co., Portland, Oreg. (1951)
7. Commercial Sash & Door, Pittsburgh, Pa. (1951)
8. Inman-Poulson Lumber Co. (1954)
9. Western Logging Co. (1954)
10. Saginaw Timber Co.
11. Feather River Pine Mills (1955)
12. Oregon-Mesabi Corp. (timber tracts) (1955)
13. Hammond Lumber Corp., San Francisco (timber holdings, finishing plants) (1956)
14. Sand (Charles E.) Plywood Co., Portland, Oreg. (building materials) (1956)

15. Coos Bay Lumber Co. (1956)
16. Williams Lumber Co., Enfield, N.C. (1957)
17. Denny Veneer Co., Roseboro, N.C. (partial) (1958)
18. Booth-Kelly Lumber Co., Springfield, Oreg. (1959)
19. Skelton Logging Co. (1959)
20. W. M. Ritter Lumber Co., Inc., Roanoke, Va. (lumber and wood products) (1960)
21. Pilot Rock Lumber Co., Inc., Pilot Rock, Oreg. (timber and lumber mills) (1960)

Weyerhaeuser Co.:

1. Washington Veneer Co. (1940)
2. Drew Timber Co. (1940)
3. Coos Bay Logging Co., North Bend, Oreg. (assets $7,186,607) (1944)
4. Kruse-Banks Shipyard, North Bend, Oreg. (1945)
5. Ewauna Box Co., Klamath Falls, Oreg. (1948)
6. Grandin-Coast Co. (1948)
7. Snoqualmie Falls Lumber Co. (purchased residual ownership) (1948)
8. Willapa Harbor Lumber Mills (purchased residual ownership) (1949)
9. White River Lumber Co. (purchased residual ownership) (1949)
10. Woodard (W. A.) Lumber Co., Cottage Grove, Oreg. (1956)
11. Hawaiian Pineapple Co. Ltd., Honolulu, T. H. (Honolulu corrugated and shipping container plant) (1957)
12. Kieckhefer Container Co. (1957)
13. Eddy Paper Co. (1957)
14. United Wood Corp., West Memphis, Ark. (1959)
15. Corrugated Containers Inc., Hartford, Conn. (corrugated shipping containers) (1960)
16. Lebanite Products Division of Cascade Plywood Corp. (1960)
17. Rilco Laminated Products Inc. (1960)
18. Roddis Plywood Corp. (1960)

## Rationale for Mergers in the Douglas-Fir Lumber Industry

In order to determine why the merger movement in the lumber industry has been relatively intense during the decade of the 1950's, the author conducted interviews with 18 people who have been involved in one way or another in merger activity. During the interviews, 23 separate mergers involving 10 acquiring firms and 23 acquired firms were discussed. Motives were examined from both the acquired firm and the acquiring firm point of view.

The limitations of this empirical study of merger motives should be clearly understood. The sample is not a large one, nor is it representative of all the mergers during any period. While the number of mergers examined is probably large enough to indicate the principal reasons for mergers, a larger sample would certainly increase the variety of less important merger motives. Further, an inquiry into motives for human behavior is never quite as simple as it first appears. A major management decision is a complex of many forces. The former owner of an acquired firm may not be able to indicate, with confidence, the single major factor that caused him to sell his firm. Several forces may have been present, any of which, in the absence of the others, might still have resulted in the same decision to sell. Because of the decision-making complexity and because the study is based upon a simple rather than a complete survey of all mergers, the conclusions must be interpreted cautiously.

One further limitation results from the nondisclosure agreement consummated prior to each interview. The executives interviewed were assured that firm names would not be associated with information gathered in the interviews. This nondisclosure limitation, of course, does not apply to already published information.

## Merger Motives from the Acquired Firm Point of View

The interview design was based upon the division of merger motives into tax considerations and nontax considerations, each with the following subcategories:

1. Tax motives for selling
    a. estate tax considerations
    b. capital gains vs. ordinary income tax considerations
2. Nontax motives for selling
    a. management considerations
    b. investment difficulties
    c. financial difficulties

The above interview design is adapted from another study of merger motives concerned with a cross section of the U. S. economy. The same interview design was used in order to make comparisons possible between motives found for mergers in the lumber industry and merger motivation found in the more broadly based study (Butters et al., 1951).

## Tax Motives of Acquired Firms

In the Butters, Lintner, and Cary study of 104 mergers involving manufacturing companies and occurring from 1940 through 1949, the conclusion was reached that "Taxes constituted an important reason for the sale of about one-tenth of the total number of selling companies . . ." (Butters et al. 1951, p. 232). Taxes were found to be a more important consideration motivating the sale of a large firm than of a small firm.

Estate tax considerations. — For lumber mergers, 2 of the 23 acquired firms cited estate tax considerations as an important factor leading to a merger. In one of these, involving a $17 million cash transaction, estate taxes were important but were not held to be the prime factor leading to the sale. In the words of the owner-seller, "the cash requirements to pay inheritance taxes would have stripped the estate of cash." In this instance, the merger transaction took place during the lifetime of the owner, but the second instance where estate taxes were important involved a sale after the death of principal owners. In this case, three partners died within a short period of time leaving their shares in the business to their widows. Cash was not available to pay inheritance taxes, and the enterprise was sold to a larger firm in the same industry. In this instance, estate tax considerations appeared to be the dominant factor leading to merger.

Capital gains vs. ordinary income tax considerations.——Liquidation of a company through merger, in order to avoid the high ordinary income tax rates in favor of lower capital gains tax rates, was often mentioned as a factor leading to merger. However, in no instance was this motive given as the principal motive for merger. It can be reasoned that taking the capital gains route would be less important as a merger cause in the lumber industry than for other U. S. industries. In all 23 cases studied, the acquired enterprises also owned timber. Firms owning the natural resource, timber, have access to capital gains treatment of income from sale or use of timber without the need of sale of the entire enterprise. Capital gains treatment for timber cut during a given year became established in the Revenue Act of 1943, Section 117(k)(1), conferring upon the timber owner who cut his timber for sale or further processing within his own plants the right of treating a gain in stumpage value as a capital gain rather than ordinary income. Prior to the enactment of Section 117(k)(1), the timber owner was required to sell his stumpage or stumpage and land outright in order to get capital gains treatment. Section 117(k)(1) allowed the bookkeeping procedure of selling one's own timber to one's self for further processing. The Internal Revenue Code of 1954 contains Section 631(a) which preserves and expands Section 117(k)(1).

In harvesting timber and processing it into lumber and other products, capital gains treatment is accorded the difference in value between the cost or other basis for depletion accounting and fair market value on the first day of the taxable year in which the timber is harvested. It is widely acknowledged in the lumber industry that much of the profit from harvesting one's own timber and processing it into lumber and other products can and does stem from capital gains due to timber ownership if one has established a low cost basis relative to current fair market value. This may be documented in tax returns of the major firms in the industry. For example, in 1960, Weyerhaueser Co., the principal lumber producer in the Douglas-fir subregion and the Nation, paid Federal income taxes amounting to $23,700,000 out of $71,451,000 before-tax net income for the year.[3] The effective tax rate is 33.1 percent for comparison with the 25-percent rate prevailing on capital gains and with the 52-percent basic rate applying to corporations. For all U. S. corporations in the $50 million to $100 million tax bracket, the effective tax rate was 46 percent (U. S. Treasury Department, 1961, p. 109). For Georgia-Pacific Corp., the second largest lumber producer in the subregion, the effective Federal income tax rate was 31 percent on $22,200,000 of 1960 net profit before taxes. The effective tax rate for all U. S. corporations in the $10 million to $25 million tax bracket was 45 percent. The third and fourth largest producers in the subregion, U. S. Plywood and Pope & Talbot, had effective 1960 Federal income tax rates of 43.5 percent and 39.7 percent, respectively.

Acquired companies having income from sources other than timber ownership also realized substantial benefits from capital gains tax treatment. For example, Coos Bay Lumber Co. in 1954 paid Federal income taxes amounting to $844,611 on $2,694,903 of net income before Federal income taxes. The effective rate was 31.3 percent compared with 45 percent for all U. S. corporations in a similar tax bracket. In 1956, Coos Bay Lumber Co. was acquired by Georgia-Pacific Corp. (Georgia-Pacific Corp., 1956, p. 4). The M&M Woodworking Co. in 1955 had an effective Federal income tax rate amounting to 37.4 percent. In the following year, 1956, Simpson Timber Co. acquired M&M Woodworking Co. in a cash transaction exceeding $50,000,000.[4]

In order to take maximum advantage from the capital gains provision within the context of continued operations as an independent operator, the firm must have income from sources other than holding and harvesting timber. Such other sources might consist of lumber milling as a minimum, and preferably plywood and pulp and paper production in addition. This

[3] Company data are taken from annual reports of the respective firms.
[4] Federal Trade Commission Dock 7713, in the matter of the Simpson Timber Co. and Simpson Redwood Co., p. 4. April 20, 1960.

is necessary for two reasons: (1) Such expenses as property taxes and timber management incurred to produce a capital gain are chargeable against ordinary income which, for corporations, may be subject to a 52-percent tax bracket. (2) Fair market value at the time of harvest is not an arms-length transaction, but rather a determination based on judgment (subject to examination by the Internal Revenue Service). In this process stumpage is assigned a value. This value is thereafter considered as the cost of such timber for the purpose of further processing. The higher the assigned cost, the higher will be the capital gain subject to a low tax rate and the lower will be normal income subject to higher ordinary income tax rates. Therefore, there must be substantial ordinary income before such tax benefits may be fully realized.

For these reasons, there is an incentive for the nonintegrated timber owner to sell out and take his income via the capital gains route.[5] However, since all of the acquired enterprises studied here owned both timber reserves and some milling facilities, they already enjoyed some of the benefits of capital gains tax treatment. Thus, one would expect the study to reveal, as it does, that the capital gains tax incentive to merge would be found with less frequency than for the firms and industries studied by Butters, Lintner, and Cary.

## Nontax Motives of Acquired Firms

Nontax factors were found in the Butters, Lintner, and Cary study to constitute an important reason for sale of about nine-tenths of the total number of selling companies and were of greater importance to small acquired firms than to large firms. Butters, Lintner, and Cary concluded that, among the nontax merger motives, management considerations accounted for about half of the smaller mergers (where the acquired firm asset size was less than $15 million) and about one-fourth of the mergers involving selling firms with assets in excess of $15 million.

Management considerations as merger motives.——Principal among the management considerations is a condition described by Butters, Lintner, and Cary as follows: "Top management had become incapable of keeping up with its competition."

In this lumber industry study, more than half of the 23 acquired firms decided in favor of merger principally as a result of concluding that they were unable to compete with the larger integrated firms. This inability to compete was, in turn, commonly attributed to two related factors: lack of integration and lack of assured timber supply. Most of the interviewees

[5] For a more complete discussion of the economics of capital gains treatment for the lumber industry see pages 81-89 of: Mead, Walter J. Taxation and conservation of privately owned timber, the impact of capital gains taxes on timber resource utilization. Proceedings of Conference, University of Oregon, Eugene. 95 pp. 1959.

connected an inability to become integrated with an inability to meet competitive prices for increasingly scarce or more distant stumpage supplies. Or, conversely, an assured supply of timber was necessary in order to protect heavy investments needed to build competitive processing facilities. This motive was identified by another research study involving mergers in the lumber industry. Dealey wrote, "One of the most evident reasons is a shortage of timber supply. If a company is in such a position that it does not have sufficient timber of its own to continue operations and is not able to compete successfully for other timber, it must close its plant or sell it to a company which has available timber" (Dealey, 1958, p. 101).

One owner-manager interviewed explained that there was U. S. Forest Service timber to the east and west, but there were fully integrated producers owning timber to the north and south in close proximity to the Federal timber. He continued by pointing out that he had an efficient sawmill and a modern plywood plant and was able to sell his chips to a pulpmill; however, the market price of his chips was only $8 per unit. He argued, the same chips were worth about $20 per unit to an integrated firm with a pulp operation, because it could profit from chip conversion to pulp. Some of his competitors for Federal stumpage possessed this advantage, and he felt that this enabled them to outbid him for Federal stumpage. He also added that other producers in the area have plyboard and hardboard plants plus further degrees of integration and thereby are apparently able to outbid him for stumpage.

In a similar instance, the owner-seller justified the merger on the grounds that integration is a prerequisite to effective competition. Prior to selling, this firm considered the addition of a pulpmill to existing multiple lumber mills and a single plywood mill, but timber holdings were not adequate to completely support a fully integrated operation. Large quantities of chips would have to be purchased and, in addition, stumpage secured from Federal sources. It was known also that two other firms in the same geographical area, but with better timber positions, were also interested in establishing fully integrated units. The owner-seller being interviewed concluded that the optimum means of reaching full integration was to allow his firm to be acquired in a merger with other firms having similar interests. The result would be a far more secure raw material position. Thus, in this instance, inability to compete as an independent was the principal motive leading to the merger. But the motive may also be described as an attempt to obtain vertical integration. The family of the owner-seller became major stockholders of the surviving firm, with immediate family members in top-management positions. Vertical integration was a motive for the acquired firm in this case.

One owner of a lumber mill and a small quantity of timber pleaded, "I'm too old." The merger path was taken as the best alternative method of retiring. In another instance, "The family got old on the job. There was no steam left." There were no sons to continue the operation and "the family wanted to cash out." In yet another case, the owner-operator wished to retire and found that his sons had interests elsewhere. The firm's timber was sold for cash to two large competitors and the sawmill scrapped. And finally, in another case, management had been a "one-man show" for years and had declined in effectiveness.

Dissension among owners, who in one case were recent heirs, contributed to a merger move in two instances. In neither instance was this motive described as dominant.

Investment position of owners as a merger motive.——In two instances where the firms were running low on timber, merger offered the possibility of salvaging more than scrap value from sawmilling facilities. In both cases, the acquiring firm owned timber near that owned by the acquired firm. The sawmill thus had functional value to the buyer in addition to the value of the remaining timber. Alternatively, if merger had been rejected and operations continued until timber owned was exhausted, then a greater probability would have existed that the sawmilling facilities owned would yield only dismantled and used-equipment value.

Butters, Lintner, and Cary argued that, largely for tax reasons, "a closely held company often has a substantially greater value to a potential purchaser than to its existing owners. A large purchaser is, therefore, likely to be able to offer a price so favorable that the existing owners will feel that it would be foolhardy to decline the opportunity to consolidate their position by cashing in their gain" (Butters et al., 1951, p. 14). Although the causal relationship in the lumber industry may not be as simple, the evidence clearly indicates that acquired firms were often of substantially greater value to the buyer than to former owners, as reflected in security values. The value differential to the buyer over the seller must be sufficient to cover any capital gains tax liability to the buyer, in addition to providing the financial inducement to sell. The tax liability is limited to the low capital gains tax rate and applies only to the gain in value between original acquisition and sale.

When a merger offer is made involving a cash or stock value far in excess of normal market value for securities of the acquired company, this in itself becomes a strong motive to merge. There are abundant illustrations of the point both outside and within the lumber industry. For example, in 1961 Weyerhaeuser Co. proposed to acquire the stock of Hamilton Paper

Co., a nonlumber company. The stock of Hamilton normally traded at less than half the value of Weyerhaeuser stock, as shown in table 3. But the merger proposal offered Hamilton shareholders 9 shares of Weyerhaeuser stock for 10 of Hamilton stock. When the Hamilton shareholders received their proxy statement requesting approval of the merger, Weyerhaeuser stock was shown to have a recent closing value amounting to 36-7/8. Hamilton stock had traded throughout 1960 at an average price of about $18 per share. The exchange for Weyerhaeuser stock would yield approximately $33 of market value, an inducement to merge amounting to an 83-percent increase over the existing Hamilton stock value. Hamilton stock promptly rose in value to the $33 area in the first quarter of 1961 and was quoted at $29.50 in the proxy statement requesting merger approval. If the stockholders voted negatively, they presumably would find their stock dropping in value back to the approximately $18 level.

Table 3. — Weyerhaeuser Co. and Hamilton Paper Co. common stock prices prior to merger (midpoint between high and low for period)

| Period | Weyerhaeuser Co. | Hamilton Paper Co. |
|---|---|---|
| | ----- Dollars ----- | |
| 1959: | | |
| First quarter | 46 | 19-5/8 |
| Second quarter | 43-3/4 | 16-3/8 |
| Third quarter | 45 | 16-1/2 |
| Fourth quarter | 41-1/2 | 14-1/2 |
| 1960: | | |
| First quarter | 38-3/4 | 17-1/2 |
| Second quarter | 36-1/4 | 18-7/8 |
| Third quarter | 33 | 18-3/4 |
| Fourth quarter | 32-1/2 | 18-1/2 |
| 1961: | | |
| First quarter | 36-7/8 | -- |
| Closing prices contained in Plan of Reorganization and Agreement between Hamilton and Weyerhaeuser | 36-1/2 | 29-1/2 |

Source: Hamilton Paper Co. proxy statement, April 7, 1961.

In 1956 the International Paper Co. tendered a merger offer to Long-Bell Corp., a holding company, and the Long-Bell Lumber Co., an operating company. As shown in table 4, the common stock of Long-Bell Lumber Co. in the fourth quarter of 1955 traded at an average price of 25-1/4. By an exchange of stock, one share of Long-Bell Lumber Co. stock could be converted into 0.42642 share of International Paper Co. stock.

On August 31, 1956, International Paper stock was traded at 126-3/8; thus, one share of Long-Bell became valued through merger at $53.89. In addition, there was a contingent interest set aside to protect International Paper from loss due to a lawsuit filed by Harbor Plywood Corp. against

Long-Bell and, secondly, from unknown Federal tax liabilities of Long-Bell. This contingent interest could add as much as $3.17 to the value of the merger offer to Long-Bell stockholders. Without the contingent interest, Long-Bell Lumber Co. stockholders were offered a market value amounting to more than double (213 percent) the fourth quarter 1955 average value of their shares.

Table 4. — International Paper Co. and Long-Bell Lumber Co. common stock prices prior to merger (mid-point between high and low for period)

| Period | International Paper Co. | Long-Bell Lumber Co. |
|---|---|---|
| | Dollars | |
| 1954: | | |
| First quarter | 53-1/4 | 17-3/8 |
| Second quarter | 61-7/8 | 17-3/4 |
| Third quarter | 70 | 17-5/8 |
| Fourth quarter | 81-1/2 | 19-1/8 |
| 1955: | | |
| First quarter | 84 | 20-7/8 |
| Second quarter | 96 | 22-3/8 |
| Third quarter | 105 | 26-1/4 |
| Fourth quarter | 105-1/2 | 25-1/4 |
| 1956: | | |
| First quarter | 115 | 38-1/2 |
| Second quarter | 133 | 49-3/4 |

Source: International Paper Co. proxy statement, September 8, 1956, p. 17.

When Simpson Timber Co. acquired M&M Woodworking Co., a cash payment amounting to $35 per share was offered for M&M shares normally selling for about $15 per share (Business Week, 1956, p. 139).

A series of newspaper accounts also illustrate this merger motive. On May 29, 1959, U. S. Plywood announced an offer to purchase the assets of Booth-Kelly Lumber Co. in Springfield, Oreg., for about $85 million. In the preceding year, the stock of Booth-Kelly sold within the range of $650 to $700 per share. The U. S. Plywood offer would have netted Booth-Kelly stockholders $3,906 per share, representing a gain of 479 percent.[6] On July 13, 1959, Georgia-Pacific Corp. bypassed management and offered to purchase the outstanding stock of Booth-Kelly for $4,250 per share, or approximately $93 million for the lumber company in total.[7] The Georgia-Pacific offer represented a gain of 530 percent over the average 1958 selling price of Booth-Kelly shares. Georgia-Pacific's offer required that 51 percent or more of the Booth-Kelly stock be deposited with an intermediary bank. On July 17, 1959, more than the required number of shares were deposited and the short contest between U. S. Plywood and Georgia-Pacific was settled in favor of the latter.[8]

[6] New York Times, p. 29, May 29, 1959.
[7] New York Times, p. 37, July 13, 1959.
[8] New York Times, p. 27, July 17, 1959.

These four cases illustrate well how an attractive merger offer may be a sufficient motive, from an investment point of view, for the acquired firm (through its stockholders) to accept a merger offer in preference to continued independent operations.

Among the 23 acquired firms studied, receipt of an attractive merger offer appears to be the dominant consideration leading to sale in one instance and a very important factor, though not the dominant one, in a second case. It should be understood that in all cases the sale price at which a merger is accomplished is attractive relative to the investment value of continuing independent operations. Otherwise the sale would not have taken place.

Financial difficulties of sellers as merger motives.——Among the 23 acquired lumber firms, only one reported financial difficulties as primary condition leading to merger. In this instance, the firm owned some timber and was operating on inadequate working capital. Its lumber production was loaded directly from the green chain into railroad boxcars for shipment and sold at the end of each day to a wholesale lumber company. The seller would receive a cash advance daily, covering the sale. The wholesale lumber company, in turn, would start such loaded freight cars moving east toward their ultimate market, but without a prior purchaser or a final destination. This process, termed "transit shipping," was restricted during 1960 by order of the Interstate Commerce Commission. The consequent decline of transit shipping meant that the firm in question was no longer able to get payment from the wholesaler simultaneously, or nearly so, with production. Financial difficulties resulted, and the firm, together with its timber, was sold to a more securely financed organization.

## Merger Motives from the Acquiring Firm Point of View

Shifting now to the acquiring firm's point of view to examine factors leading to merger, we should differentiate two levels of motives. We assume that firms decide to acquire other existing firms primarily for reasons pertaining to profit maximization or stabilization. Our interest is in the second level of motives, namely, the manager's reasons for believing a merger path will in turn serve the objectives of profit maximization or stabilization. In examining this second level of motivation, the framework provided by Butters, Lintner, and Cary will again be employed. The categories of motives to be examined are as follows:

1. Tax motives for buying
2. Nontax motives for buying
    a. Vertical integration and closer utilization
    b. New product, new plant, and new production organization
    c. Financial advantage

## Tax Motives for Buying

First, concerning taxation as a motive for the acquiring firm, Butters, Lintner, and Cary concluded that this motive was "of little consequence." They found only three instances out of 104 cases studied where taxation was believed to be the principal motive. The lumber industry stands in contrast. From the acquiring firm viewpoint, taxation provides an important incentive for merger in the lumber industry, at least during the present wave of merger activity.

Capital gains income may result either from physical growth of timber, which causes value to increase, or from an increase in value of stumpage independent of growth. From 1890 to 1916, Douglas-fir stumpage values increased from $0.10 to $2.50 per thousand board feet (Kirkland, 1917, p. 35). During the last two decades, stumpage value independent of growth

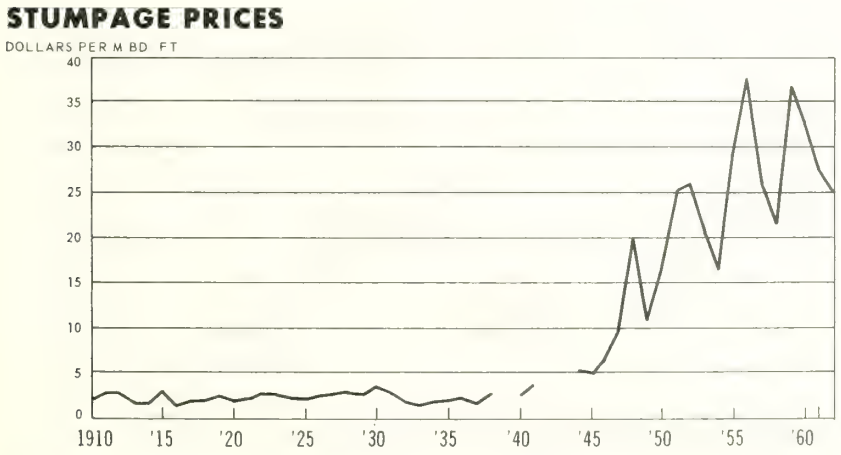



Figure 2. — Douglas-fir stumpage prices, 1910-62.

has again increased sharply. Figure 2 illustrates this remarkable development in the period of time from 1910 through 1962. Stumpage value

remained below $5 per thousand board feet until the beginning of World War II. From 1940 through 1960, Douglas-fir stumpage prices increased more than 1,300 percent. During the same period of time, the index of all commodities' wholesale prices increased only 134 percent. The management of Georgia-Pacific pointed out to stockholders that "old-growth timber, by its very nature is in diminishing supply and is a sound investment. The average cost of our total old-growth timber ownership is about $10 per thousand feet, without assigning any value to either the land or the young growth" (Georgia-Pacific Corp., 1956, p. 5). In another annual report, the president of Georgia-Pacific wrote: "Timber values are constantly increasing. Our present holdings could not be duplicated. Choice logs are in great demand and good, well-located, accessible timber is a sound and liquid investment." Though Georgia-Pacific entered the Douglas-fir lumber industry after the close of World War II, the president was able to say that the current market value of the Corporation's timber was worth approximately 2-1/2 times its cost (Georgia-Pacific Corp., 1954, p. 4).

As pointed out earlier, the growth in value of timber is of added significance in the lumber industry compared to other manufacturing industries for the reason that such gains in value are taxable as capital gains and not as ordinary income. This provides an incentive for the larger companies with corporate structure to acquire timber from others whose life span may be shorter or whose economic horizon is more limited.

In addition to the rapidly rising value of timber per thousand board feet, several other changes have taken place in rapid succession during the last two decades. First, standards of utilization have changed. Some of what were weed species of timber now have economic value. Second, trees of smaller diameter that were passed up as being of submarginal value prior to World War II are economically merchantable today. Finally, timber is still occasionally valued on the basis of old cruises which not only underestimated volume but neglected weed species and timber of small diameter as well. These three points together were identified by one careful observer as strong motives to acquire timber at bargain prices. As it is harvested and manufactured into various timber products, a large part of the profit may be treated as capital gain and taxed at relatively attractive rates.

Georgia-Pacific has been able to take maximum advantage of these factors. The Booth-Kelly timber acquired in 1959 represented one of the largest "independent" holdings of timber in the West. Management reported that "we sold some of the Booth-Kelly assets to others, but the great majority of the timber and timberlands were retained for our own use"

(Georgia-Pacific, 1959, p. 4). By selling a minority of the timber and timberland, Georgia-Pacific was able to liquidate the majority of the original cost, reducing it from $93 million to $40 million. Management was then able to say, "our over-all timber cost stands at only a fraction of current market value" (Georgia-Pacific, 1959).

Acquisitions prior to 1957 likewise produced capital gains for Georgia-Pacific. Between July 1956 and September 1957, the corporation sold 1.5 billion feet of its previously acquired timber for $30 per thousand board feet and contemplated the sale of approximately 1 billion additional feet under the same terms. Yet the corporation retained timber which was valued on the books at a cost of only $10 per thousand board feet, "a remarkably low figure for the quality of the timber reserve owned. It is sufficient to note that the present market value of Georgia-Pacific timber is considerably higher than this book value" (Blyth & Co., Inc., 1957, p. 10).

Tax motives leading to merger from the acquiring firm point of view were found by Butters, Lintner, and Cary to be of "little consequence" for the cross section of mergers included in their study. For the lumber industry, a combination of anticipated growth in stumpage value and favorable tax treatment of such capital gains, results in complex capital gain tax considerations —— an important cause leading to merger from the acquiring firm point of view.

## Nontax Motives for Buying

Remembering that pursuit of profit is the single underlying force that must be assumed behind all mergers, we may examine secondary nontax motives under three subheadings: first, vertical integration based on timber ownership plus one or more processing stages for facilitating closer utilization of raw material input; second, the need to obtain already established new products, plants, and proven production organizations; and third, an interest in financial advantages related to the money markets.

Vertical integration and closer utilization.——The most common nontax motive, accounting for 18 of the 23 mergers studied, was vertical integration for the buying firm. For the lumber industry, vertical integration is of significantly greater importance than for the cross section of industries studied by Butters, Lintner, and Cary, wherein vertical integration was a principal motive for only one-third of the mergers studied.

Vertical integration in the lumber industry is characterized by ownership of timber, logging operations, and processing facilities for one or more of the following products: lumber, veneer, plywood, particle board, hardboard, or pulp and paper. Residual from sawmills and veneer plants would

be processed into chips which in turn become raw material for a pulpmill. A firm may also utilize bark for various products and may produce electric power from burnable material not otherwise utilized.[9] Finally, vertical integration might be continued to include wholesale distribution and retail outlets.

An integrated firm can channel logs from company timberlands into their optimum economic utilization, thus enabling one manager to claim that "if stumpage is worth $20 per thousand board feet to a nonintegrated company, my company can get $40 of value per thousand board feet with full integration."

One firm was able to purchase a substantial quantity of timber plus processing plants where the existing facilities did not include equipment to remove the bark from the logs nor facilities to chip the bark-free residual. Utilization was limited to lumber and plywood. The acquiring firm was able to add a pulp and paper mill and thereby substantially increase the capitalized value of the stumpage. Whereas the management of the acquired firm had argued that their timber holdings were insufficient to justify large investments in further utilization, the acquiring firm combined the timber obtained through this and prior mergers in the same operating area and was able to justify substantial investments in further degrees of utilization.

In another instance, a major lumber producing firm was a minority partner in a processing plant sustained by timber ownership. The majority partners were unwilling to invest in further degrees of utilization. The former elected to buy out the latter and carry through additional degrees of integration. In yet another instance, the acquiring firm was principally a marketing organization, purchasing finished products from many suppliers. Backward integration was pursued in order to gain greater quality control over products being marketed.

Conclusions with reference to the vertical integration motive (a non-tax motive) for mergers, and the tax motive for mergers from the acquiring firm point of view must be interpreted with considerable caution. Where acquisition of timber is the principal factor leading one firm to acquire another, management may be motivated by a desire to improve vertical integration, while at the same time it may recognize that such timber will

[9] The gains of vertical integration might also be realized by nonintegrated firms if free and adequate markets existed at several levels of processing. Then it would be possible for a timber owner who had only a sawmill to sell his peelable logs to a veneer plant and his pulp logs and chips to a pulpmill. However, such ready markets do not exist for all nonintegrated firms. Using chips as an example, there are 22 pulpmills scattered through the Douglas-fir subregion to which chips might be sold. Sixteen of these are owned by four firms. The remaining six are owned by six firms. Because of the relatively heavy cost of transporting low value chips and the presence of few buyers necessarily clustered about the waterways of the subregion, the chip procurement market is accurately described as an oligopsony, i.e., few large buyers.

likely grow in value and that resulting values are subject to favorable tax treatment under the capital gains tax provision accorded to timber. The motives are difficult to separate, both in the mind of the decision-maker and in that of the researcher. The two factors together account for nearly all lumber industry mergers from the acquiring firm point of view.

New product, new plant, and new production organization.——This group of motives was found by Butters, Lintner, and Cary to be a major class of motives accounting for more than half of the acquisitions studied. In contrast, this class of motives is relatively unimportant in the lumber industry. All of the acquired firms owned timber in varying amounts. The principal interest centered around acquiring timber for reasons listed above.

Financial advantage.——This final nontax motive for purchase accounted for "about a dozen" cases of the 104 studied by Butters, Lintner, and Cary. They refer to "specific financial advantages such as improved marketability of stock or increased availability of outside capital." In no instance was financial advantage felt to be the most important motive for purchase in the lumber industry. Historically, firms in this industry have been owned, operated, and managed by men who have been, relatively speaking, production-oriented almost to the complete absence of a finance orientation. In recent years, a finance and marketing orientation has appeared, especially in the management of some of the new and large firms in the industry. However, even among these firms, the dominant purchase motive for mergers in which they were involved is felt to be adequately accounted for by either the vertical integration motive or the complex motive involving anticipated capital gains from timber ownership and favorable tax treatment of such gain.

## Summary

From the acquired firm's point of view, taxes appear to be less important as a merger motive in the lumber industry than in the cross section of cases studied by Butters, Lintner, and Cary. The difference is that firms owning and processing timber have access to favorable capital gains tax treatment without the need of selling out.

Second, among the management considerations, the pressure of competition was found to account for well more than half of the mergers in lumber. Management seems to believe that effective competition requires vertical integration in today's lumber industry. One owner-seller concluded that the simplest solution to competition was to sell out.

Third, investment considerations motivated mergers in this lumber industry study with approximately the same frequency as in the Butters, Lintner,

and Cary study. An offer to merge per se becomes a merger motive when it obviously is significantly more profitable to merge than to operate independently. Similarly, a fourth motive, financial difficulty, was found with approximately the same frequency.

From the acquiring firm's point of view, the tax motive was found to be far more important in the lumber industry than those industries in the general study. This arises out of past and anticipated future capital gains from holding and processing timber, subject to favorable capital gains tax treatment.

The most common motive for the surviving firm in lumber mergers, and far more important than shown in the general study, was vertical integration. The impression that there are significant economies of scale associated with vertical integration seems to be held by both parties to the merger.

A major class of nontax motives in the Butters, Lintner, and Cary general study —— obtaining a new plant, new product, and new production organization —— was represented in lumber industry mergers, but not in the same degree of importance.

# Economic Concentration In Timber Resource Ownership

In this section, we will be concerned with the concentration of economic power that exists at the first of three market levels in the Douglas-fir lumber industry: (1) timber resource ownership, (2) lumber production, and (3) wholesale lumber distribution. In order to draw conclusions about the degree of economic concentration and its trend over time, concentration ratios will be used. A concentration ratio refers to the share of a given market accounted for by a few large sellers in the market. In the context of timber resource concentration, it is a ratio where the numerator is the summation of timberland held by the "big few" and the denominator is the total ownership by all firms in the industry.

## The Present Degree of Economic Concentration In Resource Ownership

What do the facts show about the present degree of economic concentration in timber ownership and the trend of concentration over time? Table 5 has been prepared to show the present position of the four largest and the eight largest ownerships in the Douglas-fir subregion. As of 1960, the Big Four in the Douglas-fir subregion accounted for 13.7 percent of all commercial forest land in the subregion. Thus, a little more than one-seventh of all commercial forest land is held in fee ownership by the four largest producers. The eight largest firms owning commercial forest land in the area account for 17.9 percent of all commercial forest land.

The concentration of ownership by the Big Four and the Big Eight may also be viewed in terms of their share of the privately owned commercial forest land. Table 5 shows that the four largest owners account for 26.2 percent, or a little more than one-fourth of all privately owned commercial forest land in the Douglas-fir subregion. The eight largest owners account for 34.1 percent, or more than one-third of all privately owned commercial forest land.

Finally, we have estimated concentration within the private forest industry sector only. Here the Big Four hold approximately 48 percent and the Big Eight hold 62 percent of all private forest industry ownership.

Table 5. — Economic concentration in commercial forest-land ownership in the Douglas-fir subregion, 1953 and 1960

| Commercial forest land | 1953 | | | 1960 | | |
|---|---|---|---|---|---|---|
| | Area | All ownerships | Private ownerships | Area | All ownerships | Private ownerships |
| | Thousand acres | — — — Percent — — — | | Thousand acres | — — — Percent — — — | |
| Public and private ownerships | 25,455 | 100.0 | -- | 25,455 | 100.0 | -- |
| Privately owned | 13,325 | 52.3 | 100.0 | 13,325 | 52.3 | 100.0 |
| Four largest private ownerships | 2,988 | 11.7 | 22.4 | 3,493 | 13.7 | 26.2 |
| Eight largest private ownerships | 3,656 | 14.4 | 27.4 | 4,549 | 17.9 | 34.1 |

Source: 1960 data supplied by cooperating firms or developed from published annual reports or Federal Trade Commission records on mergers; however, public and private totals for 1960 are same as for 1953. Data for 1953 developed from records supplied by U. S. Forest Service (1958, p. 548).

Within the four largest ownerships there is a high degree of concentration. The largest commercial forest-land owner in the Douglas-fir subregion owns well more than half (61.6 percent) of the acreage shown for the Big Four. Further, the single largest firm's holdings account for nearly half (47.3 percent) of the eight largest ownerships in the Douglas-fir subregion.

Concentration in timberland ownership may also be viewed in terms of those ownerships in excess of 50,000 acres (see table 6). In 1953 there were 23 such ownerships out of a total of 67,983 ownerships in the Douglas-fir subregion. These ownerships accounted for 5,009,000 acres out of a total private ownership of 13,325,000 acres. Thus, the 23 largest ownerships were only three one-hundredths of 1 percent (0.03 percent) of the total number of timberland owners but they owned more than 37 percent of all private timberland.

Table 6. — Concentration in private timberland ownership in the Douglas-fir subregion and selected other regions, 1953

| Item | Ownerships | | Area | | Average size of ownership |
|---|---|---|---|---|---|
| | Number | Percent | Thousand acres | Percent | |
| | | | | | Acres |
| Douglas-fir subregion: | | | | | |
| Less than 50,000 acres | 67,960 | 99.966 | 8,316 | 62.410 | 122 |
| 50,000 acres and larger | 23 | 0.034 | 5,009 | 37.590 | 217,783 |
| All private holdings | 67,983 | 100.000 | 13,325 | 100.000 | 196 |
| South Atlantic: | | | | | |
| Less than 50,000 acres | 594,409 | 99.996 | 38,510 | 91.395 | 65 |
| 50,000 acres and larger | 23 | 0.004 | 3,626 | 8.605 | 157,652 |
| All private holdings | 594,432 | 100.000 | 42,136 | 100.000 | 71 |
| Southeast: | | | | | |
| Less than 50,000 acres | 778,447 | 99.989 | 73,882 | 84.731 | 95 |
| 50,000 acres and larger | 82 | 0.011 | 13,314 | 15.269 | 162,366 |
| All private holdings | 778,529 | 100.000 | 87,196 | 100.000 | 112 |

Source: U. S. Forest Service (1958, p. 553).

Other regions are shown also in table 6 for the purpose of comparison, not in order to establish a norm. By chance, there are also 23 firms in the South Atlantic region holding 50,000 or more acres of timberland. This represents a far smaller percent of the total number of timberland owners, and the degree of concentration accounted for by the 23 largest is much smaller than for the Douglas-fir subregion. In the Southeast, a larger number of firms having 50,000 acres or more account for a smaller percent of the total acreage than is found in the Douglas-fir subregion. Hence, again the degree of concentration is considerably smaller. In California, fewer firms (16) are in the 50,000 acres or larger class, but they control a slightly higher percent of total timberland within the State. Hence, in terms of the concentration ratio method of analysis, economic concentration in timberland ownership is greater in California than in the Douglas-fir subregion.[10]

One should not attempt to use the comparative data shown in table 6 as the basis for establishing a norm for concentration ratios in timberland ownership. The southern pine subregion grows small trees rapidly and a larger proportion of the crop is devoted to pulp use. The quantity of timber per acre in the South is very small relative to the Douglas-fir subregion. As shown in table 7, the average volume of live sawtimber per acre of privately owned Douglas-fir subregion forest land amounts to 20,300 board feet. In contrast, the South Atlantic and southeastern regions contain about 2,000 board feet per acre on private timberland. Secondly, by custom in the South, timberland owned in smaller parcels by independent farmers is often managed under contract for the pulp companies that are also substantial timber owners. Therefore, the large timber owners may control substantial amounts of timberland in addition to their fee ownership. In contrast, there is relatively little similar controlled-but-not-owned timberland in the Douglas-fir subregion.

Table 7. — Volume of sawtimber per acre

| Region | Net volume of live sawtimber, private | Commercial forest land, private | Average per acre |
|---|---|---|---|
| | Million board feet | Thousand acres | Thousand board feet |
| Douglas-fir subregion | 270,872 | 13,325 | 20.3 |
| South Atlantic | 97,958 | 42,136 | 2.3 |
| Southeast | 124,425 | 87,196 | 1.4 |

Source: U .S. Forest Service (1958, pp. 553 and 555).

Before interpreting the significance of the present degree of economic concentration in Douglas-fir subregion timber ownership, one should have a clear understanding of the different ownership classes in the subregion

10 Some of the large firms in the 50,000 acres or larger class are also in this large class within the Douglas-fir subregion.

and of the different means of measuring such ownership. Table 8 shows a breakdown of all ownerships into its several parts. We find that in 1953 Federal ownership or trusteeship, which includes Indian lands, accounted for 38.1 percent of the total acreage in the Douglas-fir subregion, 48.5 percent of the net volume of timber, and 51.6 percent of the sawtimber stands.[11] Privately owned forest land accounted for 52.3 percent of the total acreage, 45.6 percent of the net volume, and 43.3 percent of the sawtimber stands. These figures reveal that a higher proportion of the Federal ownership or trusteeship holds virgin old-growth timber and a larger share of the private ownership consists of cutover lands and new young forests.

Table 8. — Commercial forest area and net volume on commercial forest land, by ownership in the Douglas-fir subregion, 1953

| Ownership | Commercial forest land | | Sawtimber stands | | Commercial forest | | |
|---|---|---|---|---|---|---|---|
| | Area | Percent | Area | Percent | Net volume | Percent all ownerships | Percent private |
| | Thousand acres | | Thousand acres | | Million bd. ft. | | |
| Public: | | | | | | | |
| Federal or trusteeship | 9,707 | 38.2 | 7,540 | 51.6 | 288,403 | 48.5 | -- |
| State | 1,971 | 7.7 | 593 | 4.1 | 28,553 | 4.8 | -- |
| County or municipal | 452 | 1.8 | 148 | 1.0 | 6,547 | 1.1 | -- |
| All public | 12,130 | 47.7 | 8,281 | 56.7 | 323,503 | 54.4 | -- |
| Private: | | | | | | | |
| Farm | -- | -- | -- | -- | 13,103 | 2.2 | 4.8 |
| Forest industries and others | -- | -- | -- | -- | 257,769 | 43.4 | 95.2 |
| All private | 13,325 | 52.3 | 6,330 | 43.3 | 270,872 | 45.6 | 100.0 |
| All ownerships | 25,455 | 100.0 | 14,611 | 100.0 | 594,375 | 100.0 | -- |

Source: U. S. Forest Service (1958, pp. 548 and 555).

Table 8 also reveals that for the Douglas-fir subregion, timber in farm ownership is of relative insignificance, being only 4.8 percent of the total privately owned commercial forest net volume while 95.2 percent is owned by nonfarm forest owners, mostly forest industries. In this respect, the Douglas-fir subregion differs markedly from other regions in the United States. For example, in the South, 45 percent of private sawtimber volume is in farm woodlot ownership (U. S. Forest Service, 1958, p. 554).

The ownership data shown in table 8 document what is widely known — that the greatest single concentration of control over timber and timberland is in the hands of the Federal Government. A question automatically appears and was raised by Professor Weintraub: "Is the Forest Service a monopolist?" Professor Weintraub discussed this point with reference to the consequences of concentrated control by a public agency (Weintraub, 1958, pp. 150-153).

11 "Timber Resources for America's Future" defines sawtimber as stands of trees having a minimum net volume per acre of 4,000 board feet, International 1/4-inch rule.

From the point of view of economic analysis, interest in monopoly is restricted to the consequences of monopoly behavior. Behavior of a noncompetitive industry is of economic concern because, through price and output decisions, the distribution of income may be altered in favor of the monopolist compared with the pattern allowed by competition. As a consequence, the allocation of resources through an economy will differ from the pattern dictated by a free price mechanism. As a second consideration, monopoly is of concern to economic analysis through its effect on technological improvements and product innovations. Weintraub (1958) concludes:

> **Everything hinges, then, on the market behavior of the single seller; whether the consequences are exactly those of competition, or whether price is higher and production is lower, as under monopoly, depends on the seller's conduct. So far there has not been any evidence to suggest that the Forest Service has so manipulated its offerings as to maximize the aggregate sum of proceeds to it. The facts seem to be quite otherwise, to-wit, that the volume of offerings has approached pretty close to the total that could be processed with funds available and in light of the difficulty of opening new areas because of the access road situation . . . . To make the charge of 'monopoly' stick, therefore, it would have to be demonstrated that the Forest Service has consciously managed its sales offerings with a design of enlarging its aggregate sales proceeds by narrowing its stumpage offerings.**

Even if the behavior of a public agency were similar to that of a private monopolist, the consequences would still be of relatively little significance. Where private monopoly profits appear, those favored few able to benefit from monopoly profits would gain substantially through greater capital gains, higher dividends, and higher salaries or the bonus equivalent. The gains would be highly concentrated, except as they are distributed through public donations, tax payments, and the like. In contrast, the monopoly profit realized by monopolistic behavior of a public agency would be more widely distributed in the form of either lower taxes than would otherwise be necessary or through public expenditures on such items as schools, roads, national defense, etc.

## The Trend of Economic Concentration In Resource Ownership

By piecing together scanty information and developing additional information, it is possible to draw some conclusions concerning the trend of concentration in resource ownership. From data given previously in table 5,

we find that from 1953 to 1960, merger activity in the lumber industry has significantly increased concentration ratios in timberland ownership. Ownership by the Big Four increased from 2,988,000 acres to 3,493,000 acres. Concentration ratios for the Big Four increased from 11.7 percent to 13.7 percent of all commercial forest land and from 22.4 to 26.2 percent of all private commercial forest land. The increase in concentration among the eight largest ownerships was slightly greater. By expanding ownership from 3,656,000 acres to 4,549,000 acres, the ratios for the Big Eight grew from 14.4 percent to 17.9 percent of all commercial forest land and from 27.4 to 34.1 percent of all private commercial forest land.

The 43-year period from 1910 to 1953 may be compared by relating ownership data for the States of Oregon and Washington in total. Information for the Douglas-fir subregion is not available since data for the 1910 base were not broken down by subregion. The available data are shown in table 9. The 1910 data reflect the large land grants made by Congress to the railroads. The principal source of timber for Weyerhaeuser Timber Co. was the Northern Pacific Railroad grant from Congress, acquired in part by Weyerhaeuser in 1899. The Northern Pacific Railroad remained (in 1910) the third largest holder of timberland in the two States.

The composition of the four largest firms changed between 1910 and 1953. Only one firm is a member of both the 1910 and the 1953 Big Four. There is a substantial decline in resource ownership concentration over the 43-year period. Acreage held by the Big Four in 1953, for the two States in combination, declined from 5,941,000 acres to 3,714,000 acres. The 1953 acreage held by the Big Four is only 63 percent of the 1910 holdings. In the two States separately, a similar deconcentration took place. Acreage held by the four largest firms in Oregon in 1953 was only 52 percent of the 1910 figure. For Washington, the 1953 percentage is 71 percent of the earlier period.

Table 9. — Resource ownership concentration, 1910 and 1953

| Item | Oregon | Washington | Oregon and Washington |
|---|---|---|---|
| Total commercial forest land, 1953 ——— M acres— | 25,875 | 19,490 | 45,365 |
| Total private commercial forest land, 1953 ——— M acres— | 9,768 | 9,806 | 19,574 |
| Four largest holders, 1953[1] | | | |
| ——— M acres— | 1,587 | 2,454 | 3,714 |
| ——— percent of total commercial forest land— | 6.1 | 12.6 | 8.2 |
| ——— percent of total private forest land— | 16.2 | 25.0 | 19.0 |
| Four largest holders, 1910[1] | | | |
| ——— M acres— | 3,045 | 3,438 | 5,941 |
| ——— percent of 1953 total commercial forest land— | 11.8 | 17.7 | 13.1 |
| Eight largest holders in 1910 by company: | | | |
| Southern Pacific Railroad ——— M acres— | 2,079 | — | 2,079 |
| Weyerhaeuser Timber Co. ——— M acres— | 393 | 1,533 | 1,926 |
| Northern Pacific Railroad ——— M acres— | — | 1,612 | 1,612 |
| Booth-Kelly ——— M acres— | 324 | — | 324 |
| Chicago Milwaukee and St. Paul Railroad — M acres— | — | 276 | 276 |
| C. A. Smith interests ——— M acres— | 249 | — | 249 |
| Wheeler interests ——— M acres— | 129 | — | 129 |
| T. B. Walker interests, Missouri Lumber and Land Exchange interests ——— M acres— | — | 17 | 17 |

[1] In each case, four largest holders are based on each State separately and on the two States combined. For this reason, total for the line is not the sum of two States. The four largest in 1910 are not the same as the four largest in 1953.

Sources: Data for 1910 from U. S. Bureau of Corporations (1914, pp. 173-176); data for 1953 developed from data supplied by U. S. Forest Service.

In 1953, we find that the Big Four ownership in Oregon and Washington accounted for 8.2 percent of all 1953 commercial forest land (both private and public) and 19 percent of private commercial forest land.

Three years after the Bureau of Corporations' report on land ownership was published covering the year 1910, another review of land tenure was made.[12] Cary observed, "The general conclusion drawn from all the data obtained is that timber buying and consolidation of property was largely checked in Oregon by the year 1912. That this check in timber buying is permanent is not, however, to be inferred."

The Capper Report published in 1920 concluded that "Since 1910 the three largest holdings in this region (Oregon and Washington) have been decreased" (U. S. Forest Service, 1920, p. 61).

During the period 1910 to 1953, one major contribution to deconcentration in private ownership was made when the Federal Government revested approximately 2.5 million acres of land granted in 1866 to the Oregon and California Railroad Co. The timber contained on the land was not of great value at the time, and the railroad, in spite of its land grant, fell into financial difficulties. The railroad was in receivership when the Southern Pacific Railroad Co. leased it in 1887. The Government was able to prove that the grantee failed to comply with the terms of the grant, and the Oregon District Court held that the unsold lands were to be forfeited

[12] Cary, Austin. Timber ownership and lumber production in the Douglas fir region. 1917. Unpublished manuscript prepared for U. S. Dept. of Agriculture. On file School of Forestry Library, University of California, Berkeley.

to the Government. The Supreme Court reversed the lower court's decision, however, and suggested that Congress enact legislation providing for the disposition of the unsold grant lands.[13]

Further contributing to deconcentration, the Weyerhaeuser Timber Co. sold approximately 250,000 acres of its timberland chiefly to operating companies. In its initial years, Weyerhaeuser Timber Co. was primarily interested in holding timber and only later became an operating company. Similarly, the Northern Pacific Railroad Co. sold approximately 522,000 acres of timberland in Washington to operating companies.

The decline in concentration from 1910 to 1953 primarily reflects a transition from temporary railroad ownership, resulting from a nonrecurring land-grant situation, to a more permanent land-tenure position. The increase in concentration from 1953 to 1960 may be viewed as a continuation of this transition to what is probably a more permanent ownership position.

## Possible Unfavorable Effects of Increased Concentration in Resource Ownership

The present degree of concentration requires interpretation. We need to establish the meaning of the concentration ratios shown in tables 5 and 6. First, a given degree of concentration in resource ownership may have a more undesirable effect on competition than the same degree of concentration in industrial production distant from an equally limited resource base. For example, the four largest firms producing motors and generators account for 48 percent of total shipments of these products. This higher degree of concentration may be of less significance than a similar degree of concentration in timberland ownership. New plants may be constructed by new firms entering the business of manufacturing motors and generators which, in turn, would develop new competition for the existing firms. Additional competition cannot be established in timberland ownership with equal ease. The amount of land devoted to timber production may be increased only by shifting land from farm or other uses. To produce a merchantable timber crop requires about 60 years on the best timber growing sites in the Douglas-fir subregion. Thus, new supply cannot be established either with equal ease or within a comparable time period to offer effective competition.

Second, all of the eight largest timberland-owning firms are also periodic bidders and buyers of Federal timber. The firms having substantial

[13] For a full description of the revesting procedure, see: Ballaine, Wesley C. The revested Oregon and California railroad grant lands: a problem in land management. Land Econ. 29: 219-232. 1953.

timberland holdings containing large quantities of mature timber are in a preferred bidding position. Such firms have a timber reserve to supply their mills in the event that competition forces stumpage prices to high levels in a given sale. The firm without reserve timber may be forced to bid relatively high prices in order to keep its processing plants operating. Again, the firm with substantial reserves is in a position to take only the more favorable sales. To the extent that timber and timberland holdings are concentrated, the benefits of the reserve supply will be correspondingly concentrated.

Third, as was illustrated in figure 2, stumpage prices developed from bidding for National Forest timber have increased sharply since World War II. Firms holding timber over all or part of this period of rapid stumpage price increase have a substantial competitive advantage in lumber and other production.[14] In contrast, the firm buying stumpage for current needs must pay current prices, and such stumpage must be logged over a relatively short period of years. Because the cost of log input for the firm holding timber acquired prior to all or part of the recent price increase will be much lower than for the firm currently buying stumpage, relatively large profits may be earned by the former. To the extent that ownership of low-cost stumpage is concentrated, the cost advantages outlined above will also be concentrated.

A fourth important competitive consequence arises from the facts that timberland is immovable, growing stock is economically immovable, and, in the absence of relatively cheap water transportation, heavy marginal cost of hauling logs by truck or rail restricts the geographical area of effective competition. Timber is offered for sale in a given location. Processors who may effectively compete for a given timber offering are those located relatively close to the timber. Rarely can a mill with more than a 50-mile truck haul compete effectively with mills in the vicinity of the sale. To the extent that private timber surrounding the Federal timber is concentrated in one or a few holdings, there will be fewer independent and competing mills in the area of the Federal timber sale. A high degree of concentration in timberland ownership in the vicinity of a Federal timber sale, for example, may substantially reduce competition for such timber.

[14] Low stumpage prices for timber acquired years earlier do not, however, show the fact that the timber-owning firm must pay annual property taxes on the land and timber held, must obtain or forego a fair rate of return on funds invested in timber, and must also meet other charges of timber management such as protection costs. Excepting imputed interest, these costs are deductible for the purpose of computing income taxes against ordinary income, while a capital gain is taxable at not more than the 25-percent capital gain tax rate.

## Possible Benefits from Increased Concentration in Resource Ownership

The above interpretation concludes that the greater the concentration in resource ownership, the greater performance will diverge from that theoretically produced by a more competitive structure. However, the analysis is not complete until the other half of the case is examined. There is evidence to support a claim of beneficial performance resulting from concentration of timber ownership in a few large units.

Research carried on and published in 1948 by the U. S. Forest Service concluded that "Large private owners, on the average, treat their lands better than the small owners" (U. S. Forest Service, 1948, p. 48). The character of timber cutting on private lands is shown in table 10.

The Forest Service analysis revealed that "poor" and "destructive" cutting were found more frequently on small holdings than on large, and that "fair," "good," and "high-order" cutting were found more frequently on large than on small holdings. Further, the Forest Service found that "On the public lands cutting is notably better than on private lands" (U. S. Forest Service, 1948, p. 47). It should be noted that this study was based on nationwide data and may not correctly depict the Douglas-fir subregion condition.

In a more recent study, the same performance pattern was found both nationwide and for the Douglas-fir subregion. The Forest Service reported that "Productivity of recently cut areas on private lands is directly related to the size class of ownership — the smaller the ownership, the lower the proportion of recently cut land in the upper productivity class" (U. S. Forest Service, 1958, p. 238). Judgment concerning the level of productivity was based upon the degree of existing stocking, the prospective stocking, the species composition, and the presence of premature cutting.

Table 10. — Character of timber cutting on private lands by size of holding, United States, 1945
(In percent)

| Size of holding | Character of cutting[1] | | | | |
|---|---|---|---|---|---|
| | High-order | Good | Fair | Poor | Destructive |
| Small[2] | 0 | 4 | 25 | 63 | 8 |
| Medium[2] | 1 | 7 | 31 | 50 | 11 |
| Large[2] | 5 | 24 | 39 | 28 | 4 |

[1] According to definitions employed by the Forest Service, "high-order" cutting requires the best types of harvest cutting which will maintain quality and quantity yields consistent with the full productive capacity of the land. Wherever needed, it requires cultural practices such as planting, timber-stand improvement cutting, thinnings, and control of grazing.

"Good" cutting requires good silviculture that leaves the land in possession of desirable species in condition for vigorous growth in the immediate future. It is substantially better than fair cutting.

"Fair" cutting marks the beginning of cutting practices which will maintain on the land any reasonable stock of growing timber in species that are desirable and marketable.

"Poor" cutting leaves the land with a limited means for natural reproduction, often in the form of remnant seed trees. It often causes deterioration of species with the consequent reduction in both quality and quantity of forest growth.

"Destructive" cutting leaves the land without timber values and without means for natural reproduction.

[2] Small, less than 5,000 acres; medium, 5,000 to 50,000 acres; and large, 50,000 acres or more. Source: U. S. Forest Service (1948, p. 48).

Table 11 shows the productivity rating in terms of upper, medium, or lower, by size class, for the Douglas-fir subregion. We find a strong correlation within each productivity class, such that the larger the size class of ownership, the larger will be the percent of land classified in the upper productivity group.

One might reasonably expect to find better management practices in large timber holdings, generally operated by wood manufacturing corporations, than in small private timber holdings.

Large firms expect to be in business for periods far exceeding the lifetimes of their present management and stockholders. Decision making may more frequently be premised on long-term considerations rather than short-term. Reforestation to produce intermediate crops from thinnings in 30 to 50 years and a final crop in perhaps 60 to 80 years may be a more rational economic act for a firm with an indefinite life, given a relatively attractive discounted rate of return. For a small enterprise, based upon the limited life of the owners and upon their present needs, an investment decision involving returns delayed for decades may not seem worthwhile, even though the discounted rate of return may be attractive.[15]

[15] If a reliable free market for timberland containing immature timber was believed to exist, then even the small firm with a relatively short time horizon might profitably make capital outlays for reforestation. It could then expect to sell the land with its immature crop for a reasonable return.

Table 11. — Productivity of recently cut forest land by size class, Douglas-fir subregion, 1953 (In percent)

| Size class of ownership | Proportion of operating area by productivity class | | |
|---|---|---|---|
| | Upper | Medium | Lower |
| 10-100 acres | 59 | 34 | 7 |
| 100-500 acres | 57 | 27 | 16 |
| 500-5,000 acres | 63 | 27 | 10 |
| 5,000-50,000 acres | 75 | 16 | 9 |
| 50,000 acres and larger | 94 | 4 | 2 |

Source: U. S. Forest Service (1958, p. 608).

There may be additional welfare benefits resulting from more concentrated timberland ownership. When the timber resources of a given producer are sufficiently large to allow lower elevation logging during the more severe winter weather, and high elevation logging during other periods, a more stable pattern of seasonal employment in logging and lumber operations will likely result. Further, if economic resources of the larger companies allow the construction of all-weather roads into winter logging operations, more stable seasonal employment patterns will again result. Evidence on seasonal employment patterns indicates that the largest firm in the lumber industry does, indeed, have a considerably more stable pattern of employment than is found in the lumber industry as a whole. The seasonal employment index for the lumber division of Weyerhaeuser Co. shows the lowest employment month to be only 5 percent below average for the year. In contrast, the employment index for "Lumber and Other Wood Products" in the State of Oregon shows a normal decline at its lowest month amounting to 25 percent. The same series for the State of Washington shows a normal decline amounting to 23 percent.[16]

## Summary

The present degree of concentration in resource ownership within the Douglas-fir subregion is low relative to concentration ratios elsewhere in the American economy. But the ratios themselves are highly concentrated where the largest firm owns nearly half of the Big Eight ownership and one-sixth of all private commercial forest land in the subregion. More than half of the sawtimber volume is held by public agencies, principally the U. S. Forest Service.

The degree of economic concentration in private timberland ownership involves serious public policy issues since concentration in timber

[16] The seasonal character of employment in the Douglas-fir lumber industry was explored elsewhere. See: Mead, Walter J. The forest products economy of the Pacific Northwest. Land Econ. 32:127-133. 1956.

ownership may carry with it concentrated advantages in bidding for Federal stumpage.

On the other hand, there is evidence to support the claim of welfare advantages for the Nation resulting from large timberland ownerships. Evidence was produced indicating that silviculturally more intensive resource management is correlated with size of landownership. Additional welfare advantages may follow from a higher degree of timber resource utilization, of research, and of economic stability associated with a larger resource base and more diversified operations.

The trend of concentration in timber resource ownership has passed through two phases from 1910 to 1960. It is clear that a significant degree of deconcentration took place from the early part of the 20th century to its midpoint although timberland ownership was passing from relatively temporary railroad ownership to more permanent industrial and Government ownership.

One may speculate about the course of events in the 1960's. As we found in table 5, the level of concentration among the Big Four and the Big Eight holders of timberland is still relatively small. The eight largest holders of timberland account for approximately one-third of all privately owned commercial forest land. If we assume that economic pressure for full utilization continues, further merger activity resulting in higher timber resource concentration ratios seems likely to follow in the decade of the 1960's.

# Economic Concentration In Lumber Production

The concept of a lumber producing industry for the Douglas-fir subregion is subject to serious shortcomings. There is obviously a high degree of substitution between Douglas-fir lumber on one hand and ponderosa pine or southern pine on the other. The degree of substitution is relatively high compared, for example, with the degree of substitution between lumber and brick or aluminum as alternative building materials. However, as was pointed out earlier, the Douglas-fir subregion itself contains a high concentration of the Nation's lumber production. Douglas-fir accounts for a large share of the construction lumber; and for certain uses requiring large timbers from old-growth trees, the Douglas-fir subregion occupies an even more exclusive position.

Even though the concept of a Douglas-fir lumber industry has the aforementioned technical shortcomings, it is still pertinent and useful to inquire into the trend of economic concentration within this important segment of the total lumber industry. But partly because of these shortcomings and partly for purposes of comparison, concentration ratios will be shown for the total United States lumber industry as well as the Douglas-fir subregion and certain intermediate industry concepts.

## Economic Concentration In the United States Lumber Industry

In the past, the approach of the Bureau of the Census in identifying concentration ratios for various industries has been to use standard industry classifications. Both employment and value added by manufacture have traditionally been measured by classifying each leading firm into a single industry class. Thus, a firm primarily engaged in lumber production, but in addition producing chips, veneer, broom handles, and so forth, would be classed in the lumber industry, and all of its value added by manufacture and employment would be credited to the lumber industry. Because this approach has been the principal one used by the Bureau of the Census, it is commonly used to compare trends in economic concentration over time.

With the introduction of electronic computers to tabulate census data, information produced from the 1954 census may be calculated in terms

of a more useful concept, the product classification. By this classification method, the shipments of each product of a plant are classified in the industry to which that product primarily belongs. Thus, in the above illustration, lumber output would be classified in the appropriate lumber industry classification, veneer shipments would be classified in the veneer industry, etc. Because this method was first put into use in 1954, it is not possible to make historical comparisons analyzing the Bureau of the Census data.[17]

By use of the newer product classification approach, we find, as shown in table 12, a very low degree of economic concentration accounted for by the 4, 8, and 20 largest firms. In the sawmill and planing mill products classification, the Big Four account for only 6 percent of the total value of shipments of sawmill and planing mill products. Sawmill and planing mill products is one of 426 4-digit product classes in United States manufacturing industries analyzed by the Senate Subcommittee in its concentration study. Of these 426 4-digit product classes, only 5 have lower concentration ratios for the four largest firms than is found for the sawmill and planing mill products class. In terms of the 8 largest firms and 20 largest firms, only two product classes have lower concentration ratios than sawmill and planing mill products. The two with lower concentration ratios are (1) fur goods and (2) women's suits, coats, and skirts (U. S. Congress, 1957a, p. 163).

Table 12. — Concentration ratios for the United States lumber and wood products industries, 1954 (product classification method)

| Product classification | Standard industrial classification number | Value of shipments | Concentration ratios; percent of total value of shipments accounted for by — | | |
|---|---|---|---|---|---|
| | | | Four largest firms | Eight largest firms | Twenty largest firms |
| | | M dollars | | | |
| Sawmills and planing mills products | 2421 | 3,037,326 | 6 | 8 | 13 |
| Dressed lumber, except flooring | 24212 | 1,606,192 | 10 | 13 | 19 |
| Veneer | 2422 | 124,139 | 8 | 14 | 28 |
| Softwood veneer | 24222 | 41,212 | 24 | 39 | 72 |
| Plywood | 2432 | 504,725 | 16 | 24 | 40 |
| Softwood plywood, interior type | 24322 | 247,841 | 16 | 26 | 47 |
| Softwood plywood, exterior type | 24323 | 87,266 | 22 | 36 | 64 |

Source: U. S. Congress (1957a, p. 46).

[17] For a discussion of the industry classification and product classification methods, see U. S. Congress report (1957a, p. 3).

A more specialized product (5-digit), "dressed lumber except flooring," has a slightly higher degree of concentration, the four largest firms accounting for 10 percent of total value of shipments. Other subclasses of output within the standard industrial classification 24 are also shown in table 12. All of the wood products subclasses show a highly competitive structure. Of the 1,023 5-digit product classes analyzed in the Senate study, only 18 have lower concentration ratios for the Big Four than is shown in table 13 for "dressed lumber except flooring." Only eight of the 5-digit product classes have lower ratios for the Big Eight firms, and only three product classes have lower ratios than the Big Twenty shippers of "dressed lumber except flooring" (U. S. Congress, 1957a, p. 163).

In order to establish a norm, we may examine concentration ratios in industries producing products competitive with lumber. As shown in table 13, the sawmill and planing mill products category has one of the most competitive structures of any of the products competing for construction expenditures. Only "concrete block and brick" has a more competitive structure, and this industry does not sell in a national market. The average concentration ratio for the industries shown is far in excess of that prevailing in the lumber industry and ranges as high as 98 percent of all product shipment value accounted for by the Big Four in the plate glass industry.

Table 13. — Concentration ratios for lumber and other products based on value of product shipments and, for lumber, based on volume of production, 1954 (product classification method)

(In percent of total)

| Product classification or product | Standard industrial classification | Concentration ratios | | |
|---|---|---|---|---|
| | | Four largest firms | Eight largest firms | Twenty largest firms |
| **VALUE OF PRODUCT SHIPMENTS[1]** | | | | |
| Concrete block and brick | 32711 | 3 | 5 | 10 |
| Sawmill and planing mill products | 2421 | 6 | 8 | 13 |
| Veneer | 2422 | 8 | 14 | 28 |
| Metal doors, sash and trim | 3442 | 12 | 19 | 29 |
| Brick and hollow tile | 3251 | 13 | 20 | 33 |
| Plywood | 2432 | 16 | 24 | 40 |
| Paper and paperboard | 2612 | 19 | 31 | 46 |
| Pulp | 2611 | 29 | 42 | 61 |
| Cement, hydraulic | 3241 | 31 | 48 | 73 |
| Plastic materials | 2823 | 45 | 61 | 78 |
| Insulating board and hard pressed wood-fiber board | 26132 | 61 | 84 | 99 |
| Gypsum products | 3272 | 89 | 97 | 99 |
| Structural steel shapes and piling | 33126 | 92 | 97 | [2] |
| Aluminum plate and sheet | 33521 | 93 | 98 | 99 |
| Plate glass | 32112 | 98 | 99 | 99 |
| **VOLUME OF PRODUCTION[3]** | | | | |
| Lumber: | | | | |
| Douglas-fir subregion | -- | 16.6 | 22.1 | 31.6 |
| Pacific Northwest | -- | 14.1 | 19.0 | 27.1 |
| Pacific coast | -- | 10.2 | 13.9 | 20.9 |
| United States | -- | 5.1 | 7.0 | 10.7 |

[1] Percent is of total for U. S. for the product class indicated in column 1. Size ranking is also within all of U. S.

[2] Not applicable.

[3] Base of each percent is the total lumber production for the region indicated in column 1. Size ranking is also within the indicated region.

Source: Data for lumber developed from directories of the forest industries published by The Lumberman and The Timberman, Portland, Oreg., 1961, 1956, and 1949. For all other product class groups, from U. S. Congress report (1957a, pp. 46-55).

In the bottom section of table 13, concentration ratios are shown on a physical production basis for the total United States lumber production as well as for the Douglas-fir subregion, for the Pacific Northwest (Washington and Oregon) and for the Pacific coast (Washington, Oregon, and California). With the lumber industry centered in the Douglas-fir subregion, concentration ratios are naturally higher for this subregion than for the United States as a whole. But even so, compared with the whole United States, the 16.6 percent of total subregional output accounted for by the Big Four producers in the Douglas-fir subregion continues to place the Douglas-fir lumber industry in that class of industries having a highly competitive structure.[18]

[18] Table 13 shows a higher ratio when concentration is measured in terms of value of product rather than in terms of physical production. As shown in table 13, the 20 largest shippers of sawmill and planing mill products account for 13 percent of the total value of product shipments, but only 10.7 percent of the volume production. This difference would be expected since the larger firms process a much higher proportion of their total lumber production through kiln-drying than would be true for the total industry. This fact would be reflected in a **value** of product measure but not in a **physical** product measure.

If we now use the measure of industrial concentration more commonly employed by the Bureau of the Census, the industry classification, comparison over time is possible for the lumber industry for the years 1947 and 1954. Data for the lumber industry prior to 1947 are not comparable with 1947 or 1954 data by reason of a change in the system of industrial classification.

Data shown in table 14 indicate a clear increase in concentration ratios for the lumber industry. The four largest producers in the United States in the sawmill and planing mill category increased their share of the market from 5 to 7 percent between 1947 and 1954. For the Big Twenty, the increase in concentration is not only more reliable but is more marked. Whereas the Big Twenty in 1947 accounted for 11 percent of industry shipments, 7 years later they accounted for 18 percent of the total market. Over the same period of time, an interesting deconcentration is shown for veneer plants and plywood plants. In 1947, plywood production was still in its early stage of growth. By 1954, knowledge of technology had spread widely and a multitude of small operations had commenced production. Production (value of shipments) had increased 2-1/2 times. Entry into veneer and plywood production requires a relatively small amount of capital, products are not widely differentiated by brand names, and all producers have access to wholesalers for distribution of their product. Many operations that in 1947 were limited to lumber became partially integrated by 1954 to include veneer and possibly plywood plants.

Table 14. — Concentration ratios for lumber, veneer, and plywood in United States, 1947 and 1954 (industry classification method)

| Industry classification | Standard industrial classification number | Number of companies in class | Value of shipments | Concentration ratios: percent of total value of shipments accounted for by — | | |
|---|---|---|---|---|---|---|
| | | | | Four largest firms | Eight largest firms | Twenty largest firms |
| | | | Million dollars | | | |
| Sawmills and planing mills: | 2421 | | | | | |
| 1954 | | 16,594 | 3,247 | 7 | 11 | 18 |
| 1947 | | 19,223 | 2,519 | 5 | 7 | 11 |
| Veneer mills: | 2422 | | | | | |
| 1954 | | 252 | 121 | 9 | 15 | 30 |
| 1947 | | 136 | 67 | 20 | 31 | 52 |
| Plywood plants: | 2432 | | | | | |
| 1954 | | 219 | 515 | 17 | 25 | 42 |
| 1947 | | 142 | 272 | 22 | 34 | 56 |

Source: U. S. Congress (1957a, p. 202).

Comparable data are available over a longer time span, covering lumber production from mills producing 50 million board feet of lumber or more per year. This information is presented in table 15 and shows that the percent of total output accounted for by mills producing 50 million feet per year or more declined from 25.8 percent of total output in 1929 to a low of 11 percent of total output in 1947 and has since expanded to 17.7 percent of total output in 1960. These data are useful in showing the market importance of an absolute size class, including the very great importance of the size class in 1929, its decline during the depression and continuing decline to 1947, and its subsequent modest increase. The importance of this absolute size class is considerably diminished over the 31-year period from 1929 to 1960.

Table 15. — U. S. sawmills in the size class producing 50 million board feet or more per year

| Year | Number of mills in 50 million and larger production class (1)) | Total number of mills in industry (2) | Ratio of column 1 to column 2 (3) | Production from mills in 50 million and larger production class (4) | Total U. S. lumber production (5) | Ratio of column 4 to column 5 (6) |
|---|---|---|---|---|---|---|
| | | | Percent | Million bd. ft. | Million bd. ft. | Percent |
| 1960 | 65 | 30,918 | 0.2 | 5,827 | 32,880 | 17.7 |
| 1959 | 89 | 34,113 | .3 | 6,870 | 37,166 | 18.5 |
| 1958 | 67 | 31,645 | .2 | 6,056 | 33,385 | 18.1 |
| 1957 | 67 | 37,597 | .2 | 6,092 | 32,901 | 18.5 |
| 1954 | 60 | 45,929 | .1 | 4,872 | 36,356 | 13.4 |
| 1947 | 43 | 53,109 | .1 | 3,894 | 35,404 | 11.0 |
| 1938 | 44 | 14,644 | .3 | 3,420 | 21,646 | 15.8 |
| 1929 | 120 | 20,037 | .6 | 9,516 | 36,886 | 25.8 |

Source: For 1957-60, U. S. Bureau of the Census (1961, 1962); for 1929-54, National Lumber Manufacturer's Association (1961, p. 23).

The data also indicate that over the 9-year period, 1938 to 1947, there was a significant decrease in concentration in lumber production. The number of sawmills in the 50 million board feet or larger size class was approximately the same in 1938 and 1947. From the fact that approximately the same number of the largest mills accounted for 15.8 percent of total output in 1938 and only 11 percent of total output in 1947, we may conclude that a deconcentration took place over the 9-year period. From 1947 through 1960, however, the number of mills in this large size class increased 51 percent, accompanied by a 50-percent increase in production from such mills. Since total United States lumber production declined modestly, it follows that the gain in market share for the largest mills, accounting for less than 0.1 percent of the total number of mills in 1947, came at the expense of the others representing more than 99.9 percent of the total United States lumber mills. From the facts shown in table 15, we may

conclude that the large mills have become increasingly important in lumber production from 1947 to 1960 and that there is increased economic concentration in the sense defined and discussed in this paper.

From data published in the directories of the forest industries, it is possible to develop reasonably accurate lumber production data by firms. This has been done in table 16. For the United States lumber industry as a whole, the increase in concentration from 1947 to 1954 is rather modest. In the ensuing 6 years, however, a sharp increase in concentration took place. Compared with concentration ratios for other industries in the United States economy, the lumber industry structure remains as one of the most competitive to be found in the economy. This judgment is made even in face of the accelerated merger movement in the United States lumber industry in the decade of the 1950's and in face of the significant increase in concentration ratios during this period. Concentration ratios for the 8 largest and the 20 largest lumber producing firms are correspondingly modest, although both show significant increases over the 13-year period 1947 to 1960.

Table 16. — Economic concentration in the lumber industry, 1947, 1954, 1959, and 1960[1]

| Region and year | Four largest producers | | Eight largest producers | | Twenty largest producers | | Total production |
|---|---|---|---|---|---|---|---|
| | Million feet production | Percent of total | Million feet production | Percent of total | Million feet production | Percent of total | |
| Douglas-fir subregion: | | | | | | | |
| 1960 | 1,936 | 23.9 | 2,379 | 29.4 | 3,292 | 40.6 | 8,100 |
| 1959 | 1,961 | 21.5 | 2,503 | 27.5 | 3,404 | 37.4 | 9,104 |
| 1954 | 1,538 | 16.6 | 2,055 | 22.1 | 2,931 | 31.6 | 9,283 |
| 1947 | 1,429 | 15.9 | 1,847 | 20.6 | 2,688 | 30.0 | 8,962 |
| Pacific Northwest: | | | | | | | |
| 1960 | 2,244 | 20.2 | 2,901 | 26.2 | 3,969 | 35.8 | 11,082 |
| 1959 | 2,201 | 18.4 | 2,938 | 24.6 | 4,158 | 34.8 | 11,962 |
| 1954 | 1,670 | 14.1 | 2,258 | 19.0 | 3,222 | 27.1 | 11,879 |
| 1947 | 1,533 | 14.2 | 2,033 | 18.8 | 2,988 | 27.6 | 10,808 |
| Pacific coast: | | | | | | | |
| 1960 | 2,482 | 15.3 | 3,335 | 20.5 | 4,756 | 29.3 | 16,257 |
| 1959 | 2,440 | 13.5 | 3,389 | 18.8 | 5,000 | 27.7 | 18,025 |
| 1954 | 1,735 | 10.2 | 2,368 | 13.9 | 3,558 | 20.9 | 16,992 |
| 1947 | 1,615 | 11.4 | 2,140 | 15.1 | 3,248 | 22.8 | 14,216 |
| United States: | | | | | | | |
| 1960 | 3,021 | 9.2 | 4,104 | 12.5 | 5,872 | 17.9 | 32,880 |
| 1959 | 2,941 | 7.9 | 4,114 | 11.1 | 6,135 | 16.5 | 37,166 |
| 1954 | 1,846 | 5.1 | 2,528 | 7.0 | 3,874 | 10.7 | 36,356 |
| 1947 | 1,687 | 4.8 | 2,274 | 6.4 | 3,471 | 9.8 | 35,404 |

[1] Both the ranking and the percents apply within the region indicated in column 1.
Source: Developed from directories of the forest industries published by The Lumberman and The Timberman, Portland, Oreg., 1961, 1956, and 1949.

Professor Stigler urged the economics profession in its analysis of the structure of industry to include imports as an addition to domestic production for the purpose of calculating concentration ratios (Stigler, 1942). This

practice may change judgment concerning the performance of a highly oligopolistic industry. The principle would apply well to the automobile industry under the impact of European cars. For the United States lumber industry, the inclusion of imports makes an already competitive industrial structure even more so. In 1960, imports equaled 12 percent of domestic production and this percentage was up sharply from 1947 (see table 17). In 1960, the share of total lumber production accounted for by the Big Four is reduced from 9.2 percent to 8.2 percent by the inclusion of imports. However, little is known of the extent to which imports are from foreign producers wholly or partly owned by the Big Four.

Table 17. — Concentration ratios for four largest U. S. lumber producers, adjusted to include imports

| Year | U. S. lumber production | Imports | Total U. S. production plus imports | Ratio of imports to domestic production | Concentration ratios for U. S. lumber industry (four largest producers) | |
|---|---|---|---|---|---|---|
| | | | | | With imports included | As shown in table 16 |
| | Million bd. ft. | Million bd. ft. | Million bd. ft. | Percent | Percent | Percent |
| 1960 | 32,880 | 3,931 | 36,811 | 12 | 8.2 | 9.2 |
| 1959 | 37,166 | 4,077 | 41,243 | 11 | 7.1 | 7.9 |
| 1954 | 36,356 | 3,066 | 39,422 | 8 | 4.7 | 5.1 |
| 1947 | 35,404 | 1,314 | 36,718 | 4 | 4.6 | 4.8 |

Sources: For production, U. S. Bureau of the Census (1962). For imports, 1961 issues of "Business Statistics," weekly supplement to "Survey of Current Business," Office of Business Economics, U. S. Department of Commerce.

In summary, an examination of economic concentration in the total U. S. lumber industry confirms a highly competitive structure with the four largest firms shipping only 6 percent of all sawmill and planing mill products. Few other industries in the Nation have a more competitive structure.

Comparing concentration ratios among the building industries competing with lumber, we found the latter to have an uncommonly low concentration ratio. In contrast, 98 percent of all plate glass shipped in the United States originated with the four largest firms.

An analysis of trends over time revealed that from 1947 to 1954 a clear increase in concentration was recorded for the U. S. lumber industry. During the same time period, the Nation's veneer and plywood producers became less concentrated. By another type of measure, a longer time span was examined. From 1938 to 1947, deconcentration was registered for lumber, followed by increasing concentration.

## Economic Concentration in the Douglas-Fir Lumber Industry

Returning to table 16 for our concern with the Douglas-fir lumber industry, we find that the Big Four producers in 1947 accounted for only 15.9 percent of the subregion's total lumber production. By 1954 this degree of economic concentration had changed only slightly, to 16.6 percent. But in the next 6 years the merger movement in the lumber industry showed its impact and the concentration ratio for the Big Four increased to 23.9 percent. While this represents a considerable increase in degree of economic concentration over a 6-year period, relative to concentration ratios found in other industries in the U. S. economy, the Douglas-fir lumber industry must still be judged highly competitive, the merger movement notwithstanding.

Concentration ratios for the Big Eight and Big Twenty similarly increased sharply in the last half of the 1950's, but continued to keep the Douglas-fir lumber industry in the category of highly competitive industries. The reader may again refer to table 13 to compare concentration ratios for industries competing with lumber for construction expenditures.

The degree of economic concentration is also shown in table 16 for the Pacific Northwest (Oregon and Washington), the Pacific coast (California, Oregon, and Washington), and the United States. A similar increase in concentration is shown, with the most significant change occurring in the 1954 to 1960 period.

Table 16 is a summary of more detailed information provided in table 18. The latter table shows the dynamics of the 20 largest firms. Weyerhaeuser Co. maintained and expanded its commanding position in the lumber industry and all of its parts over not only the 13-year span of history shown but over a much longer period. Weyerhaeuser's leadership has grown steadily from 8.8 percent of total production within the Douglas-fir subregion in 1947, to 9.7 percent in 1954, to 12.9 percent in 1959, and 14.6 percent in 1960. In 1960, Weyerhaeuser produced 3.4 times as much lumber as its nearest rival and accounted for half the output of the eight largest firms. Yet Weyerhaeuser's share of either the Douglas-fir subregion output or total U. S. output is small relative to that of the leading firm in other major U. S. industries.

## Table 18. — Twenty largest lumber producing firms, by region and year

### DOUGLAS-FIR SUBREGION

1947

| Rank | Name | Production | Share of Douglas-fir subregion production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Timber Co. | 780,000 | 8.8 | 8.8 |
| 2. | Long-Bell Lumber Co. | 291,100 | 3.2 | 12.0 |
| 3. | Pope & Talbot, Inc. | 186,330 | 2.1 | 14.1 |
| 4. | Coos Bay Timber Co. | 162,003 | 1.8 | 15.9 |
| 5. | C. D. Johnson Lumber Corp. | 123,367 | 1.4 | 17.3 |
| 6. | Irwin & Lyons, Inc. | 108,190 | 1.2 | 18.5 |
| 7. | Inman-Poulson Timber Co. | 92,907 | 1.0 | 19.5 |
| 8. | Gardiner Lumber Co. | 92,782 | 1.0 | 20.5 |
| 9. | Santiam Lumber Co. | 92,692 | 1.0 | 21.5 |
| 10. | Shepard & Morse Lumber Co. | 89,885 | 1.0 | 22.5 |
| 11. | Willamette Valley Lumber Co. | 80,902 | .9 | 23.4 |
| 12. | Medford Corp. | 76,864 | .9 | 24.3 |
| 13. | Oregon American Lumber Corp. | 72,400 | .8 | 25.1 |
| 14. | Schafer Bros. Lumber Shingle Co. | 72,000 | .8 | 25.9 |
| 15. | St. Paul & Tacoma Lumber Co. | 69,254 | .8 | 26.7 |
| 16. | West Oregon Lumber Co. | 64,342 | .7 | 27.4 |
| 17. | Roseburg Lumber Co. | 58,562 | .7 | 28.1 |
| 18. | Walton Lumber Co., Inc. | 56,552 | .6 | 28.7 |
| 19. | Edward Hines Lumber Co. | 54,842 | .6 | 29.3 |
| 20. | Rosboro Lumber Co. | 52,924 | .6 | 30.0 |

1954

| Rank | Name | Production | Share of Douglas-fir subregion production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Timber Co. | 900,000 | 9.7 | 9.7 |
| 2. | Long-Bell Lumber Co. | 282,342 | 3.0 | 12.7 |
| 3. | Pope & Talbot, Inc. | 190,282 | 2.0 | 14.7 |
| 4. | Coos Bay Timber Co. | 165,415 | 1.8 | 16.5 |
| 5. | Georgia-Pacific Corp. | 147,267 | 1.6 | 18.1 |
| 6. | Willamette Valley Lumber Co. | 146,118 | 1.6 | 19.7 |
| 7. | Roseburg Lumber Co. | 130,000 | 1.4 | 21.1 |
| 8. | Santiam Lumber Co. | 94,575 | 1.0 | 22.1 |
| 9. | Rainier Manufacturing Co. | 89,257 | 1.0 | 23.1 |
| 10. | Simpson Logging Co. | 86,690 | .9 | 24.0 |
| 11. | Irwin & Lyons, Inc. | 84,567 | .9 | 24.9 |
| 12. | Ross Lumber Co. | 78,766 | .8 | 25.7 |
| 13. | Medford Corp. | 75,795 | .8 | 26.5 |
| 14. | Diamond Lumber Co. | 71,431 | .8 | 27.3 |
| 15. | Edward Hines Lumber Co. | 69,998 | .7 | 28.0 |
| 16. | St. Paul & Tacoma Lumber Co. | 68,019 | .7 | 28.7 |
| 17. | LHL Lumber Co. | 65,380 | .7 | 29.4 |
| 18. | Clemens Forest Products, Inc. | 62,842 | .7 | 30.1 |
| 19. | Robert Dollar Co. | 62,338 | .7 | 30.8 |
| 20. | Booth-Kelly Lumber Co. | 59,859 | .6 | 31.4 |

## Table 18. — Twenty largest lumber producing firms, by region and year — Continued

**DOUGLAS-FIR SUBREGION**

1959

| Rank | Name | Production | Share of Douglas-fir subregion production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Co. | 1,170,000 | 12.9 | 12.9 |
| 2. | Georgia-Pacific Corp. | 335,349 | 3.7 | 16.6 |
| 3. | United States Plywood Corp. | 242,238 | 2.7 | 19.3 |
| 4. | Pope & Talbot, Inc. | 213,102 | 2.3 | 21.6 |
| 5. | Simpson Logging Co. | 158,360 | 1.7 | 23.3 |
| 6. | International Paper Co. | 154,419 | 1.7 | 25.0 |
| 7. | Santiam Lumber Co. | 115,000 | 1.3 | 26.3 |
| 8. | Willamette Valley Lumber Co. | 114,175 | 1.3 | 27.6 |
| 9. | Roseburg Lumber Co. | 90,000 | 1.0 | 28.6 |
| 10. | Rainier Manufacturing Co. | 87,610 | 1.0 | 29.6 |
| 11. | St. Regis Paper Co. | 82,311 | .9 | 30.5 |
| 12. | Al Pierce Lumber Co. | 82,082 | .9 | 31.4 |
| 13. | Coos Head Timber Co. | 81,384 | .9 | 32.3 |
| 14. | Edward Hines Lumber Co. | 77,961 | .9 | 33.2 |
| 15. | Medford Corp. | 72,418 | .8 | 34.0 |
| 16. | Buchanan Lumber Co. | 68,282 | .8 | 34.8 |
| 17. | Aborigine Lumber Co. | 67,500 | .7 | 35.5 |
| 18. | Anderson & Middleton Lumber Co. | 64,955 | .7 | 36.2 |
| 19. | Park Loading Co. | 63,500 | .7 | 36.9 |
| 20. | Steve Wilson Co. | 63,465 | .7 | 37.6 |

1960

| Rank | Name | Production | Share of Douglas-fir subregion production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Co. | 1,187,207 | 14.6 | 14.6 |
| 2. | Georgia-Pacific Corp. | 350,000 | 4.3 | 18.9 |
| 3. | United States Plywood Corp. | 220,723 | 2.7 | 21.6 |
| 4. | Pope & Talbot, Inc. | 178,368 | 2.2 | 23.8 |
| 5. | Simpson Timber Co. | 124.137 | 1.5 | 25.3 |
| 6. | Willamette Valley Lumber Co. | 118,850 | 1.5 | 26.8 |
| 7. | Rainier Manufacturing Co. | 106,381 | 1.3 | 28.1 |
| 8. | Stomar Lumber Co. | 93,156 | 1.2 | 29.3 |
| 9. | Santiam Lumber Co. | 90,851 | 1.1 | 30.4 |
| 10. | Roseburg Lumber Co. | 90,000 | 1.1 | 31.5 |
| 11. | Coos Head Timber Co. | 88,308 | 1.1 | 32.6 |
| 12. | Edward Hines Lumber Co. | 86,185 | 1.1 | 33.7 |
| 13. | Olson-Lawyer Lumber, Inc. | 83,615 | 1.0 | 34.7 |
| 14. | St. Regis Paper Co. | 79.013 | 1.0 | 35.7 |
| 15. | Medford Corp. | 78,653 | 1.0 | 36.7 |
| 16. | International Paper Co. | 71,997 | .9 | 37.6 |
| 17. | Timber Products Co. | 67,064 | .8 | 38.4 |
| 18. | Steve Wilson Co. | 62,738 | .8 | 39.2 |
| 19. | Mountain Fir Lumber Co. | 57,810 | .7 | 39.9 |
| 20. | Clemens Forest Products, Inc. | 57,436 | .7 | 40.6 |

## Table 18. — Twenty largest lumber producing firms, by region and year — Continued

### PACIFIC NORTHWEST

1947

| Rank | Name | Production | Share of Pacific Northwest production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Timber Co. | 875,000 | 8.1 | 8.1 |
| 2. | Long-Bell Lumber Co. | 291,100 | 2.7 | 10.8 |
| 3. | Pope & Talbot, Inc. | 186,330 | 1.7 | 12.5 |
| 4. | Edward Hines Lumber Co. | 180,486 | 1.7 | 14.2 |
| 5. | Coos Bay Timber Co. | 162,003 | 1.5 | 15.7 |
| 6. | C. D. Johnson Lumber Corp. | 123,367 | 1.1 | 16.8 |
| 7. | Irwin & Lyons, Inc. | 108,190 | 1.0 | 17.8 |
| 8. | Shevlin, Hixon Co. | 106,965 | 1.0 | 18.8 |
| 9. | Inman-Poulson Timber Co. | 92,907 | .8 | 19.6 |
| 10. | Gardiner Lumber Co. | 92,782 | .8 | 20.4 |
| 11. | Santiam Lumber Co. | 92,692 | .8 | 21.2 |
| 12. | Brooks-Scanlon, Inc. | 91,905 | .8 | 22.0 |
| 13. | Shepard & Morse Lumber Co. | 89,885 | .8 | 22.8 |
| 14. | Willamette Valley Lumber Co. | 80,902 | .8 | 23.6 |
| 15. | Medford Corp. | 76,864 | .7 | 24.3 |
| 16 | Oregon American Lumber Corp. | 72,400 | .7 | 25.0 |
| 17. | Schafer Bros. Lumber & Shingle Co. | 72,000 | .7 | 25.7 |
| 18. | St. Paul & Tacoma Lumber Co. | 69,254 | .6 | 26.3 |
| 19. | West Oregon Lumber Co. | 64,342 | .6 | 26.9 |
| 20. | Roseburg Lumber Co. | 58,562 | .5 | 27.4 |

1954

| Rank | Name | Production | Share of Pacific Northwest production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Timber Co. | 1,000,000 | 8.4 | 8.4 |
| 2. | Long-Bell Lumber Co. | 282,342 | 2.4 | 10.8 |
| 3. | Edward Hines Lumber Co. | 197,060 | 1.6 | 12.4 |
| 4. | Pope & Talbot, Inc. | 190,282 | 1.6 | 14.0 |
| 5. | Coos Bay Timber Co. | 165,415 | 1.4 | 15.4 |
| 6. | Georgia-Pacific Corp. | 147,267 | 1.2 | 16.6 |
| 7. | Willamette Valley Lumber Co. | 146,118 | 1.2 | 17.8 |
| 8. | Roseburg Lumber Co. | 130,000 | 1.1 | 18.9 |
| 9. | Diamond Match Co. | 119,837 | 1.0 | 19.9 |
| 10. | Santiam Lumber Co. | 94,574 | .8 | 20.7 |
| 11. | Rainier Manufacturing Co. | 89,257 | .8 | 21.5 |
| 12. | Simpson Logging Co. | 86,690 | .7 | 22.2 |
| 13. | Irwin & Lyons, Inc. | 84,567 | .7 | 22.9 |
| 14. | Ross Lumber Co. | 78,766 | .7 | 23.6 |
| 15. | Medford Corp. | 75,795 | .6 | 24.2 |
| 16. | Diamond Lumber Co. | 71,431 | .6 | 24.8 |
| 17. | St. Paul & Tacoma Lumber Co. | 68,019 | .6 | 25.4 |
| 18. | Brooks-Scanlon, Inc. | 67,183 | .5 | 25.9 |
| 19. | LHL Lumber Co. | 65,380 | .5 | 26.4 |
| 20. | Clemens Forest Products, Inc. | 62,842 | .5 | 27.0 |

## Table 18. — Twenty largest lumber producing firms, by region and year — Continued

PACIFIC NORTHWEST

1959

| Rank | Name | Production | Share of Pacific Northwest production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Co. | 1,300,000 | 10.9 | 10.9 |
| 2. | Georgia-Pacific Corp. | 335,349 | 2.8 | 13.7 |
| 3. | Boise Cascade Corp. | 323,490 | 2.7 | 16.4 |
| 4. | United States Plywood Corp. | 242,238 | 2.0 | 18.4 |
| 5. | Pope & Talbot, Inc. | 213,102 | 1.8 | 20.2 |
| 6. | Edward Hines Lumber Co. | 210,614 | 1.8 | 22.0 |
| 7. | Simpson Logging Co. | 158,360 | 1.3 | 23.3 |
| 8. | International Paper Co. | 154,419 | 1.3 | 24.6 |
| 9. | St. Regis Paper Co. | 144,639 | 1.2 | 25.8 |
| 10. | J. Herbert Bate Co. | 115,000 | 1.0 | 26.8 |
| 11. | Santiam Lumber Co. | 115,000 | 1.0 | 27.8 |
| 12. | Willamette Valley Lumber Co. | 114,175 | 1.0 | 28.8 |
| 13. | Brooks-Scanlon, Inc. | 97,871 | .8 | 29.6 |
| 14. | Roseburg Lumber Co. | 90,000 | .8 | 30.4 |
| 15. | Rainier Manufacturing Co. | 87,610 | .7 | 31.1 |
| 16. | Mountain Fir Lumber Co. | 87,607 | .7 | 31.8 |
| 17. | Kinzua Corp. | 82,990 | .7 | 32.5 |
| 18. | Al Pierce Lumber Co. | 82,082 | .7 | 33.2 |
| 19. | Coos Head Timber Co. | 81,384 | .7 | 33.9 |
| 20. | Biles-Coleman Lumber Co. | 81,000 | .7 | 34.6 |

1960

| Rank | Name | Production | Share of Pacific Northwest production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Co. | 1,308,740 | 11.8 | 11.8 |
| 2. | Georgia-Pacific Corp. | 400,000 | 3.6 | 15.4 |
| 3. | Boise Cascade Corp. | 315,021 | 2.8 | 18.2 |
| 4. | United States Plywood Corp. | 220,723 | 2.0 | 20.2 |
| 5. | Edward Hines Lumber Co. | 215,891 | 1.9 | 22.1 |
| 6. | Pope & Talbot, Inc. | 178,368 | 1.6 | 23.7 |
| 7. | St. Regis Paper Co. | 138,357 | 1.2 | 24.9 |
| 8. | Simpson Logging Co. | 124.137 | 1.1 | 26.0 |
| 9. | Willamette Valley Lumber Co. | 118,850 | 1.1 | 27.1 |
| 10. | Rainier Manufacturing Co. | 106,381 | 1.0 | 28.1 |
| 11. | Stomar Lumber Co. | 93,156 | .8 | 28.9 |
| 12. | Santiam Lumber Co. | 90,851 | .8 | 29.7 |
| 13. | Roseburg Lumber Co. | 90,000 | .8 | 30.5 |
| 14. | Coos Head Timber Co. | 88,308 | .8 | 31.3 |
| 15. | Brooks-Scanlon, Inc. | 88,109 | .8 | 32.1 |
| 16. | Olson-Lawyer Lumber, Inc. | 83,615 | .8 | 32.9 |
| 17. | Biles-Coleman Lumber Co. | 81,000 | .7 | 33.6 |
| 18. | Medford Corp. | 78,653 | .7 | 34.3 |
| 19. | Kinzua Corp. | 76,753 | .7 | 35.0 |
| 20. | International Paper Co. | 71,977 | .6 | 35.6 |

## Table 18. — Twenty largest lumber producing firms, by region and year — Continued

PACIFIC COAST

1947

| Rank | Name | Production | Share of Pacific coast production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Timber Co. | 875,000 | 6.1 | 6.1 |
| 2. | Long-Bell Lumber Co. | 372,900 | 2.6 | 8.7 |
| 3. | Pope & Talbot, Inc. | 186,330 | 1.3 | 10.0 |
| 4. | Edward Hines Lumber Co. | 180,486 | 1.3 | 11.3 |
| 5. | Coos Bay Timber Co. | 162,003 | 1.1 | 12.4 |
| 6. | C. D. Johnson Lumber Corp. | 123,367 | .9 | 13.3 |
| 7. | Fruit Growers Supply Co. | 121,000 | .9 | 14.2 |
| 8. | McCloud River Lumber Co. | 118,833 | .8 | 15.0 |
| 9. | Irwin & Lyons, Inc. | 108,190 | .8 | 15.8 |
| 10. | Pacific Lumber Co. | 107,472 | .8 | 16.6 |
| 11. | Shevlin, Hixon Co. | 106,965 | .7 | 17.3 |
| 12. | Inman-Poulson Timber Co. | 92,907 | .7 | 18.0 |
| 13. | Gardiner Lumber Co. | 92,782 | .7 | 18.7 |
| 14. | Santiam Lumber Co. | 92,692 | .7 | 19.4 |
| 15. | Hammond Lumber Co. | 92,000 | .6 | 20.0 |
| 16. | Brooks-Scanlon, Inc. | 91,905 | .6 | 20.6 |
| 17. | Shepard & Morse Lumber Co. | 89,885 | .6 | 21.2 |
| 18. | Willamette Valley Lumber Co. | 80,902 | .5 | 21.7 |
| 19. | Medford Corp. | 76,864 | .5 | 22.2 |
| 20. | Pickering Lumber Corp. | 75,590 | .5 | 22.7 |

1954

| Rank | Name | Production | Share of Pacific coast production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Timber Co. | 1,000,000 | 5.9 | 5.9 |
| 2. | Long-Bell Lumber Co. | 347,342 | 2.0 | 7.9 |
| 3. | Edward Hines Lumber Co. | 197,060 | 1.2 | 9.1 |
| 4. | Pope & Talbot, Inc. | 190,282 | 1.1 | 10.2 |
| 5. | Fruit Growers Supply Co. | 176,000 | 1.0 | 11.2 |
| 6. | Coos Bay Timber Co. | 164,415 | 1.0 | 12.2 |
| 7. | Georgia-Pacific Corp. | 147,267 | .9 | 13.1 |
| 8. | Willamette Valley Lumber Co. | 146,118 | .9 | 14.0 |
| 9. | Roseburg Lumber Co. | 130,000 | .8 | 14.8 |
| 10. | Diamond Match Co. | 119,837 | .7 | 15.5 |
| 11. | McCloud River Lumber Co. | 110,923 | .6 | 16.1 |
| 12. | United States Plywood Corp. | 98,798 | .6 | 16.7 |
| 13. | Hammond Lumber Co. | 94,966 | .5 | 17.2 |
| 14. | Santiam Lumber Co. | 94,574 | .5 | 17.7 |
| 15. | Union Lumber Co. | 94,000 | .5 | 18.2 |
| 16. | Pacific Lumber Co. | 93,310 | .5 | 18.7 |
| 17. | Ralph L. Smith Lumber Co. | 92,774 | .5 | 19.2 |
| 18. | Rainier Manufacturing Co. | 89,256 | .5 | 19.7 |
| 19. | Simpson Logging Co. | 86,690 | .5 | 20.2 |
| 20. | Irwin & Lyons, Inc. | 84,567 | .5 | 20.7 |

## Table 18. — Twenty largest lumber producing firms, by region and year — Continued

PACIFIC COAST

1959

| Rank | Name | Production | Share of Pacific coast production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Co. | 1,300,000 | 7.2 | 7.2 |
| 2. | Georgia-Pacific Corp. | 491,528 | 2.7 | 9.9 |
| 3. | United States Plywood Corp. | 324,533 | 1.8 | 11.7 |
| 4. | Boise Cascade Corp. | 323,490 | 1.8 | 13.5 |
| 5. | American Forest Products Corp. | 267,970 | 1.5 | 15.0 |
| 6. | Simpson Logging Co. | 255,660 | 1.4 | 16.4 |
| 7. | Pope & Talbot, Inc. | 213,102 | 1.2 | 17.6 |
| 8. | International Paper Co. | 212,365 | 1.2 | 18.8 |
| 9. | Edward Hines Lumber Co. | 210,614 | 1.2 | 19.9 |
| 10. | Pacific Lumber Co. | 182,928 | 1.0 | 20.9 |
| 11. | St. Regis Paper Co. | 144,639 | .8 | 21.7 |
| 12. | Ralph L. Smith Lumber Co. | 141,238 | .8 | 22.5 |
| 13. | Cheney Lumber Co. | 122,195 | .7 | 23.2 |
| 14. | McCloud River Lumber Co. | 120,535 | .7 | 23.8 |
| 15. | Aborigine Lumber Co. | 117,748 | .7 | 24.5 |
| 16. | Pickering Lumber Corp. | 116,950 | .6 | 25.1 |
| 17. | J. H. Bate Co. | 115,000 | .6 | 25.7 |
| 18. | Santiam Lumber Co. | 115,000 | .6 | 26.3 |
| 19. | Willamette Valley Lumber Co. | 114,175 | .6 | 26.9 |
| 20. | Trio Lumber Co., Inc. | 110,000 | .6 | 27.5 |

1960

| Rank | Name | Production | Share of Pacific coast production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Co. | 1,313,740 | 8.1 | 8.1 |
| 2. | Georgia-Pacific Corp. | 552,000 | 3.4 | 11.5 |
| 3. | Boise Cascade Corp. | 315,021 | 1.9 | 13.4 |
| 4. | United States Plywood Corp. | 300,767 | 1.8 | 15.2 |
| 5. | American Forest Products Corp. | 248,165 | 1.5 | 16.7 |
| 6. | Edward Hines Lumber Co. | 215,891 | 1.3 | 18.0 |
| 7. | Simpson Logging Co. | 211,472 | 1.3 | 19.3 |
| 8. | Pope & Talbot, Inc. | 178,368 | 1.1 | 20.4 |
| 9. | Pacific Lumber Co. | 166,746 | 1.0 | 21.4 |
| 10. | St. Regis Paper Co. | 138,357 | .8 | 22.2 |
| 11. | Ralph L. Smith Lumber Co. | 135,215 | .8 | 23.0 |
| 12. | Union Lumber Co. | 126,000 | .8 | 23.8 |
| 13. | International Paper Co. | 121,344 | .7 | 24.5 |
| 14. | Willamette Valley Lumber Co. | 118,850 | .7 | 25.2 |
| 15. | Diamond National Corp. | 110,247 | .7 | 25.9 |
| 16. | McCloud River Lumber Co. | 108,553 | .7 | 26.6 |
| 17. | Rainier Manufacturing Co. | 106,381 | .6 | 27.2 |
| 18. | Pickering Lumber Corp. | 101,077 | .6 | 27.8 |
| 19. | Cheney Lumber Co. | 95,000 | .6 | 28.4 |
| 20. | Stomar Lumber Co. | 93,156 | .6 | 29.0 |

## Table 18. — Twenty largest lumber producing firms, by region and year — Continued

UNITED STATES

1947

| Rank | Name | Production | Share of United States production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Timber Co. | 875,000 | 2.5 | 2.5 |
| 2. | Long-Bell Lumber Co. | 372,900 | 1.0 | 3.5 |
| 3. | Potlatch Forests, Inc. | 252,944 | .7 | 4.2 |
| 4. | Pope & Talbot, Inc. | 186,330 | .5 | 4.7 |
| 5. | Edward Hines Lumber Co. | 180,486 | .5 | 5.2 |
| 6 | Coos Bay Timber Co. | 162,003 | .5 | 5.7 |
| 7. | C. D. Johnson Lumber Corp. | 123,367 | .3 | 6.0 |
| 8. | Fruit Growers Supply Co. | 121,000 | .3 | 6.3 |
| 9. | McCloud River Lumber Co. | 118,833 | .3 | 6.6 |
| 10. | Irwin & Lyons, Inc. | 108,190 | .3 | 6.9 |
| 11. | Pacific Lumber Co. | 107,472 | .3 | 7.2 |
| 12. | Shevlin, Hixon Co. | 106,965 | .3 | 7.5 |
| 13. | Southwest Lumber Mills | 101,619 | .3 | 7.8 |
| 14. | Boise-Payette Lumber Co. | 101,542 | .3 | 8.1 |
| 15. | Inman-Poulson Timber Co. | 92,907 | .3 | 8.4 |
| 16. | Gardiner Lumber Co. | 92,782 | .3 | 8.7 |
| 17. | Santiam Lumber Co. | 92,692 | .3 | 9.0 |
| 18. | Hammond Lumber Co. | 92,000 | .2 | 9.2 |
| 19. | Brooks-Scanlon, Inc. | 91,905 | .2 | 9.4 |
| 20. | Shepard & Morse Lumber Co. | 89,885 | .2 | 9.6 |

1954

| Rank | Name | Production | Share of United States production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Timber Co. | 1,000,000 | 2.8 | 2.8 |
| 2. | Long-Bell Lumber Co. | 347,342 | .9 | 3.7 |
| 3. | Potlatch Forests, Inc. | 301,361 | .8 | 4.5 |
| 4. | Edward Hines Lumber Co. | 197,060 | .5 | 5.0 |
| 5. | Pope & Talbot, Inc. | 190,282 | .5 | 5.5 |
| 6. | Fruit Growers Supply Co. | 176,000 | .5 | 6.0 |
| 7. | Coos Bay Timber Co. | 165,415 | .5 | 6.5 |
| 8. | J. Neils Lumber Co. | 150,904 | .4 | 6.9 |
| 9. | Georgia-Pacific Corp. | 147,267 | .4 | 7.3 |
| 10. | Willamette Valley Lumber Co. | 146,118 | .4 | 7.7 |
| 11. | Roseburg Lumber Co. | 130,000 | .4 | 8.1 |
| 12. | Southwest Lumber Mills, Inc. | 123,307 | .3 | 8.4 |
| 13. | Diamond Match Co. | 119,837 | .3 | 8.7 |
| 14. | McCloud River Lumber Co. | 110,923 | .3 | 9.0 |
| 15. | United States Plywood Corp. | 98,738 | .3 | 9.3 |
| 16. | Hammond Lumber Co. | 94,966 | .3 | 9.6 |
| 17. | Santiam Lumber Co. | 94,574 | .3 | 9.9 |
| 18. | Union Lumber Co. | 94,000 | .2 | 10.1 |
| 19. | Pacific Lumber Co. | 93,310 | .2 | 10.3 |
| 20. | Ralph L. Smith Lumber Co. | 92,774 | .2 | 10.5 |

## Table 18. — Twenty largest lumber producing firms, by region and year — Continued

UNITED STATES

1959

| Rank | Name | Production | Share of United States production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Co. | 1,300,000 | 3.5 | 3.5 |
| 2. | Potlatch Forests, Inc. | 597,933 | 1.6 | 5.1 |
| 3. | Georgia-Pacific Corp. | 538,836 | 1.5 | 6.6 |
| 4. | Boise Cascade Corp. | 504,000 | 1.4 | 8.0 |
| 5. | United States Plywood Corp. | 324,433 | .9 | 8.9 |
| 6. | St. Regis Paper Co. | 301,196 | .8 | 9.7 |
| 7. | Diamond National Corp. | 280,000 | .7 | 10.4 |
| 8. | American Forest Products Corp. | 267,970 | .7 | 11.1 |
| 9. | Simpson Logging Co. | 255,660 | .7 | 11.8 |
| 10. | International Paper Co. | 230,203 | .6 | 12.4 |
| 11. | Pope & Talbot, Inc. | 213,102 | .6 | 13.0 |
| 12. | Edward Hines Lumber Co. | 210,614 | .5 | 13.5 |
| 13. | Pacific Lumber Co. | 182,928 | .5 | 14.0 |
| 14. | Southwest Forest Industries, Inc. | 164,106 | .4 | 14.4 |
| 15. | Dierks Forests, Inc. | 145,168 | .4 | 14.8 |
| 16. | Ralph L. Smith Lumber Co. | 141,238 | .4 | 15.2 |
| 17. | Cheney Lumber Co. | 122,195 | .3 | 15.5 |
| 18. | McCloud River Lumber Co. | 120,535 | .3 | 15.8 |
| 19. | Aborigine Lumber Co. | 117,748 | .3 | 16.1 |
| 20. | Pickering Lumber Co. | 116,950 | .3 | 16.4 |

1960

| Rank | Name | Production | Share of United States production | Cumulative share of production |
|---|---|---|---|---|
| | | Thousand board feet | Percent | Percent |
| 1. | Weyerhaeuser Co. | 1,328,740 | 4.0 | 4.0 |
| 2. | Georgia-Pacific Corp. | 655,902 | 2.0 | 6.0 |
| 3. | Boise Cascade Corp. | 522,830 | 1.6 | 7.6 |
| 4. | Potlatch Forests, Inc. | 513,157 | 1.6 | 9.2 |
| 5. | United States Plywood Corp. | 300,767 | .9 | 10.1 |
| 6. | St. Regis Paper Co. | 286,240 | .9 | 11.0 |
| 7. | Diamond National Corp. | 248,247 | .8 | 11.8 |
| 8. | American Forest Products Corp. | 248,165 | .8 | 12.6 |
| 9. | Edward Hines Lumber Co. | 215,891 | .6 | 13.2 |
| 10. | Simpson Lumber Co. | 211,472 | .6 | 13.8 |
| 11. | Pope & Talbot, Inc. | 178,368 | .5 | 14.3 |
| 12. | Pacific Lumber Co. | 166,746 | .5 | 14.8 |
| 13. | Southwest Forest Industries, Inc. | 154,755 | .5 | 15.3 |
| 14. | Ralph L. Smith Lumber Co. | 135,215 | .4 | 15.7 |
| 15. | Union Lumber Co. | 126,000 | .4 | 16.1 |
| 16. | Dierks Forests, Inc. | 124,066 | .4 | 16.5 |
| 17. | International Paper Co. | 121,344 | .4 | 16.9 |
| 18. | Willamette Valley Lumber Co. | 118,850 | .4 | 17.3 |
| 19. | McCloud River Lumber Co. | 108,553 | .3 | 17.6 |
| 20. | Rainier Manufacturing Co. | 106,381 | .3 | 17.9 |

The composition of the leading firms in the Douglas-fir subregion has changed sharply over the 13-year period 1947 to 1960. Only 7 of the 20 largest firms of 1947 were still in the list for 1960. There were, therefore, 13 new firms in the 1960 list. The Big Four remained the same in both composition and order from 1947 to 1954, but two of them disappeared through merger before 1959.

Georgia-Pacific became the second largest lumber producing firm in the Douglas-fir lumber industry of 1959 and had strengthened this position by 1960. This surviving corporation had absorbed four firms that had appeared on the Big Twenty list in either or both 1947 or 1954. Neither U.S. Plywood nor Weyerhaeuser[19] nor Pope & Talbot had absorbed any of the former Big Twenty firms.

A chain of mergers can be identified over the four points in time. Gardiner Lumber Co. and Oregon American Lumber Corp., appearing as numbers 8 and 13, respectively, on the 1947 list, were absorbed by Long-Bell, number 2 on the 1954 list. Long-Bell was in turn merged with International Paper Co. and became number 6 on the 1959 list and number 16 on the 1960 list.

The four largest lumber producing firms in the United States include two that are among the four largest in the Douglas-fir subregion, Weyerhaeuser Co. and Georgia-Pacific. The Big Four firms in the Pacific Northwest are the same as the Big Four in the Pacific Coast States, although the production for each differs except in the case of Weyerhaeuser Co.

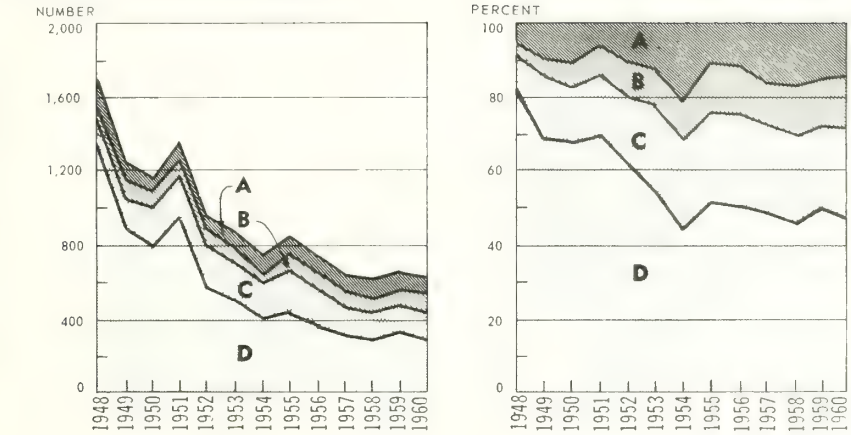
Preoccupation up to this point with the 4, 8, and 20 largest firms tends to obscure other dynamic changes that have taken place in the industrial structure of the Douglas-fir lumber industry. Significant changes have taken place in the small mill class where a large number of firms have left the industry, resulting in only a small effect on the total output or the share accounted for by the 4, 8, or 20 largest firms.

Figure 3 illustrates graphically the changes taking place from 1948 to 1960 involving principally the small mills in the Douglas-fir subregion. Total lumber production from the subregion was approximately unchanged from 1948 to 1959 but declined in 1960. Production in 1960 was 15 percent below the 1948 level. But the 1948 output was produced by 1,675 mills in the Douglas-fir subregion, whereas the 1960 output was produced by only 614 mills. The disappearance of 1,061 mills from production over this period represents a decline of 63 percent in number of producing units.

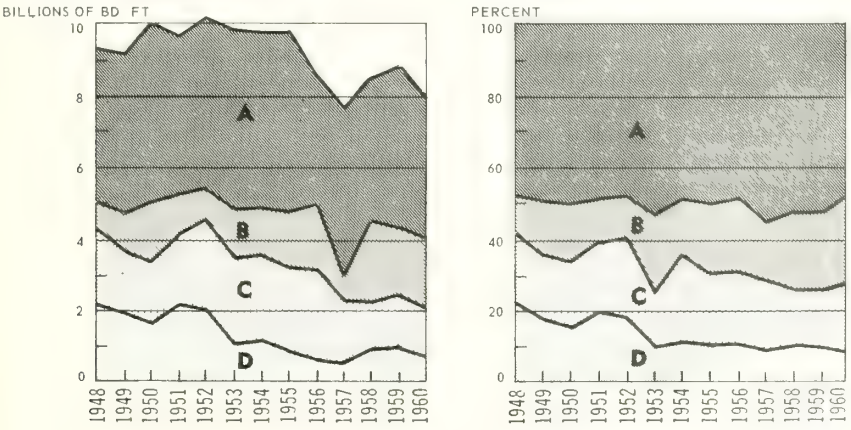
[19] Schafer Bros. Lumber & Shingle Co. was acquired by Simpson Logging Co. in 1955. Weyerhaeuser Timber Co. in turn acquired lumber milling facilities and some timberland from the former Schafer Bros. holdings.

## SAWMILLS by SIZE CLASS

### MILLS in A, B, C, D CLASSES




### TOTAL PRODUCTION




A mills ( large ) – producing 120,000 board feet or more per 8-hour shift.
B mills ( medium large ) – producing 80,000 to 119,999 board feet per 8-hour shift.
C mills ( medium small ) – producing 40,000 to 79,999 board feet per 8-hour shift.
D mills ( small ) – producing 39,999 board feet or less per 8-hour shift.

Source: Developed from data supplied by West Coast Lumbermen's Association

Figure 3. — Number of and production from sawmills in the Douglas-fir subregion by size class, 1948-60.

The number of mills making their exit from the Douglas-fir lumber industry during the increasingly unfavorable period 1948 to 1960 is almost exactly equal to the number of mills entering production during the increasingly favorable period 1933 to 1948. There were 606 mills operating in 1933 and 614 in 1960. Even further back, there were 631 mills operating in 1926, the number expanding to 883 in 1929 and declining to 441 in 1932.

Almost the entire 1948 to 1960 exit is accounted for by small mills (D class, producing less than 40,000 board feet per 8-hour shift). In 1948 there were 1,328 class D sawmills in production and in 1960 there were only 291 mills in this small class. This disappearance of 1,037 mills from the class D category represents a 78-percent decline.

The medium-small mills (defined as C mills, producing between 40,000 and 80,000 board feet per 8-hour shift) declined modestly from 191 mills in 1948 to 154 mills in 1960. This represents a disappearance of 19 percent of the 1948 C mills in production. Clearly, the great decline in small mills is not accounted for by an expansion in their output causing them to be classified as medium-small (class C) mills.

The medium-large mills (class B mills, defined as mills producing 80,000 to 119,999 board feet per 8-hour shift) increased by 26 mills, from 53 in 1948 to 89 in 1960. This represents a 68-percent increase and may be accounted for in part by some class C mills expanding output and shifting into the B category.

The large mills (class A mills, defined as mills producing 120,000 board feet or more per 8-hour shift) declined by 22 percent, from 103 mills in 1948 to 80 mills in 1960. Since the medium-small, medium-large, and large mills in total declined in number, we may infer that most small mills ceased production entirely rather than became larger. The considerable decline in number of active sawmills is not accounted for by merger activity since data reported are for plants rather than firms. The only exception to this generalization is where merger results in a mill being closed down and its supporting timber used to supply existing plants of the acquiring firm.

In 1948, small mills, representing 79 percent of the total number of mills, accounted for 24 percent of total production. In 1960, small mills accounted for only 47 percent of the total number of mills and only 8 percent of total output. On the other hand, the large mills in 1948 represented 6 percent of the total mills but produced 44 percent of total output. In 1960 the large mills, though fewer in number, represented 13 percent of total producing units and 49 percent of total output.

The most significant change in the structure of the Douglas-fir lumber industry in recent years is clearly the 1948-60 mass exodus of small mills

from the industry, almost exactly offsetting the mass entry from 1933 to 1948. At the same time the large mills, while fewer in number, accounted for a greater share of total production. Finally, concentration of output within the 4, 8, and 20 largest mills has expanded sharply, particularly in the latter half of the 1950's. Nevertheless, the lumber industry remains one of the most competitive industries in the U. S. economy, particularly so, because many of the small mills apparently could again operate if conditions became favorable.

The foregoing has outlined the structure of the lumber industry, noting both the present position and the trend over time. While the data indicate increasing economic concentration at the resource ownership level and at the production level in the decade of the 1950's, these facts do not allow us to render a judgment that the trend or current position is either "good" or "bad." To pass such judgment would require, first, agreement as to the objectives of a given industrial structure and, second, the probability of a competitive structure or oligopolistic structure serving the agreed-upon objectives. While forming a judgment concerning performance is important, it is well beyond the scope of a study concerned with the structure of an industry.

# Economic Concentration In Wholesale Lumber Distribution

The purpose of this section is to discover the degree of economic concentration in the process of wholesale lumber distribution. Knowledge of the structure of the wholesale lumber distributing function is important for at least two reasons. First, if this function is served by a few enterprisers (an oligopoly) with barriers to entry into the business, then it would be possible for a few wholesale distributors to exploit the many lumber producers. Second, even though a high degree of competition may prevail at the production level, oligopoly at the wholesale level can produce oligopolistic effects for consumers of lumber. A collusive oligopoly at the wholesale level would be able to establish noncompetitive wholesaler markups and pass the cost on to consumers.

## The Structure of Wholesale Lumber Distribution

In view of these possibilities, let us now turn to an examination of the structure of the wholesaling function. Figure 4 shows the multitude of possible routes that lumber may take between its production and final consumption. About 85 percent of all the Douglas-fir subregion lumber production moves through wholesalers. These firms take title to the lumber and extend normal trade credits. The so-called western wholesalers maintain close contact with supplying mills, buying from them and in turn selling to eastern wholesalers who have relatively close contacts with distribution yards, retailers, and large consumers. The western wholesaler may also sell directly to the same level of customers to which the eastern wholesaler attempts to sell, or the western wholesaler may utilize the services of a commission man who in turn is a step closer to the ultimate consumer.

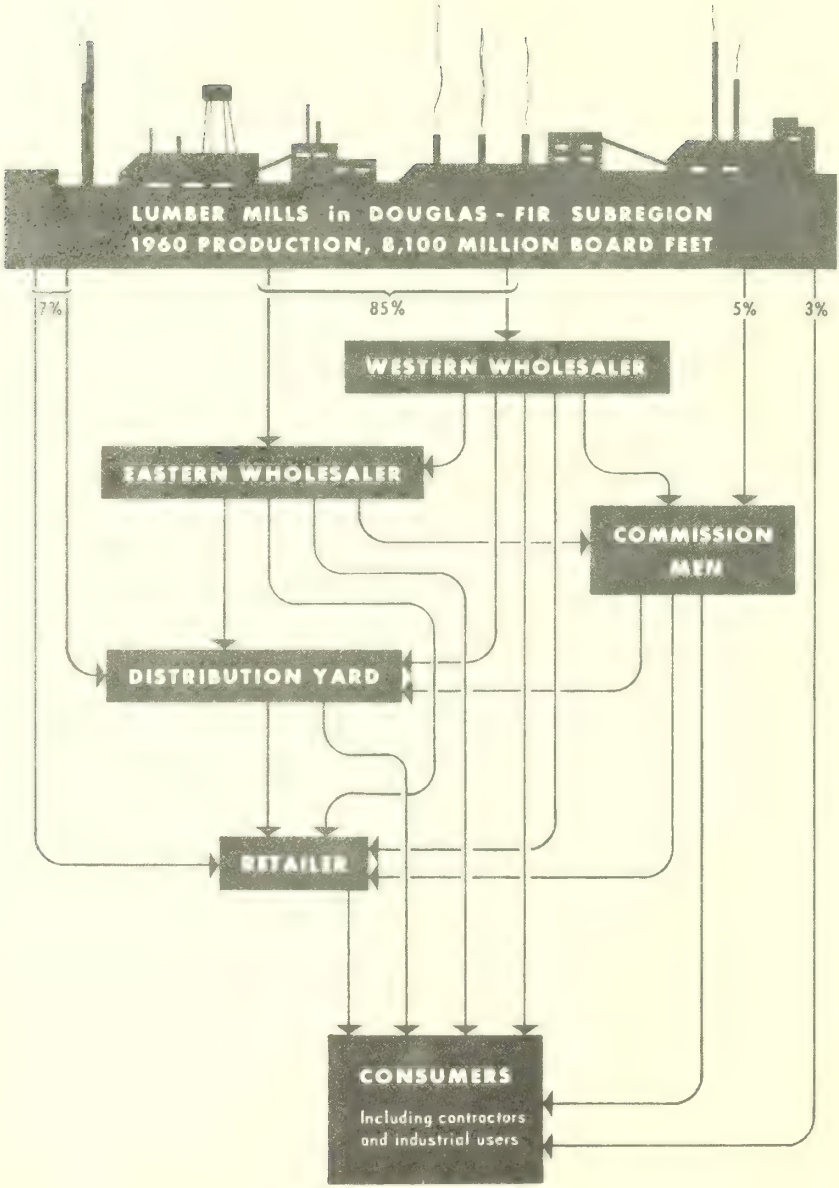



Figure 4. — Organization chart for lumber distribution.

About 7 percent of total Douglas-fir subregion lumber production is sold directly to distribution yards where lumber inventories are maintained, or directly to retailers. An estimated 5 percent of Douglas-fir subregion production is sold through commission men, who do not take title to lumber and do not generally extend credit but, rather, operate on a commission that seems to vary between $1 and $2 per thousand board feet. The remaining approximately 3 percent of Douglas-fir subregion lumber production is sold directly to consumers, including contractors and industrial users.

The wholesaling function is a highly fluid business. Two well-informed observers estimated widely different numbers of wholesalers and commission men actively engaged in the lumber distribution function. One estimate was that there are about 1,500 wholesalers (western and eastern) operating in the United States and that about 800 commission men are actively in business. Another estimate was that there are 5,000 to 6,000 wholesalers and 300 to 400 commission men. One source of the great disparity in estimates is that no precise definition exists of who constitutes a wholesaler or a commission man or a retailer. Wholesalers also commonly perform a commission service. Retailers may attempt to operate as wholesalers and wholesalers may do a retail business. Regardless of which estimate approximates the true universe, the industry is clearly not made up of a few operators with rigid barriers to entry. One wholesaler complained that "all it takes to enter this business is a telephone, a ditto machine, and $10,000 to $20,000 of working capital. Anyone can get on mailing lists to receive offerings from mills and can in turn send out price lists to potential buyers."

Though entry into the wholesaling function is relatively easy, it still may be true that a few wholesalers handle most of the volume. Table 19 shows that the three largest western wholesalers whose principal operations are in the Douglas-fir subregion handle 14.8 percent of total subregion lumber production. This market share is relatively small. It does not substantiate the hypothesis that a few large wholesalers are structurally in a position to control lumber distribution and exploit either the many lumber producers or the wholesalers, retailers, or large users to whom they sell.

Of the remaining 85 percent of the lumber supply coming from the Douglas-fir subregion, part will be accounted for not by wholesalers but by the large producers themselves who serve as not only their own wholesalers but in some cases have a string of retail yards as well. The share of the market accounted for by the four largest producers in the Douglas-fir subregion is also shown in table 19. We find that the large producer-sellers may control as much as 21.5 percent of the subregion's wholesale

lumber market and, together with the share accounted for by the three largest western wholesalers, may account for up to 36.3 percent of the market. This measure, however, involves some double counting because the large producers sell part of their output through the three western wholesalers. Therefore, 36.3 percent serves as a maximum, with the true market control accounted for by the seven largest sellers being less than 36.3 percent.

Table 19. — Wholesale lumber market shares, Douglas-fir subregion, 1959

| Item | Volume of lumber produced and/or shipped | Percent of market |
|---|---|---|
| | Million bd. ft. | |
| Three largest western wholesale lumber companies, total shipments[1] | 1,350 | 14.8 |
| Four largest producer-sellers, Douglas-fir subregion: | | |
| Weyerhaeuser Co.[2] | 1,170 | 12.8 |
| Georgia-Pacific Corp.[2] | 335 | 3.7 |
| U. S. Plywood Corp.[2] | 242 | 2.7 |
| Pope & Talbot, Inc.[2] | 213 | 2.3 |
| Total, four largest producer-sellers | 1,960 | 21.5 |
| Total, above seven sellers | 3,310 | 36.3 |
| All others | 5,794 | 63.7 |
| Total lumber production, Douglas-fir subregion | 9,104 | 100.0 |

[1] Data provided by the three wholesale lumber firms on a nondisclosure basis.
[2] Data from directories of the forest industries published by The Lumberman and The Timberman, San Francisco, 1961.

The three large western wholesalers do not restrict their buying operations to the Douglas-fir subregion. Therefore, in table 20 their share of the Pacific coast market is shown together with the production in the same three States. The three largest wholesalers handle 7.5 percent of the Pacific coast supply and the four largest producer-sellers, 13.5 percent. We, therefore, find that there is potential control over 21 percent of the Pacific coast supply, and true market control lies somewhere short of this 21 percent.

Because there is a high degree of substitution possible between lumber produced in the Douglas-fir subregion relative to the western pine subregion and the southern pine subregion, table 21 also includes concentration ratios in the wholesale market for the entire United States. The three largest wholesalers now control only 3.6 percent of the total United States market and the four largest producer-sellers, 7.9 percent. Together, there is a potential control of 11.5 percent with actual control somewhere below this figure.

Table 20. — Wholesale lumber market shares, California, Oregon, and Washington, 1959

| Item | Volume of lumber produced and/or shipped | Percent of market |
|---|---|---|
| | Million bd. ft. | |
| Three largest western wholesale lumber companies, total shipments[1] | 1,350 | 7.5 |
| Four largest producer-sellers, West Coast: | | |
| Weyerhaeuser Co.[2] | 1,300 | 7.2 |
| Georgia-Pacific Corp.[2] | 492 | 2.7 |
| U. S. Plywood Corp.[2] | 325 | 1.8 |
| Boise Cascade Corp.[2] | 323 | 1.8 |
| Total, four largest producer-sellers | 2,440 | 13.5 |
| Total, above seven sellers | 3,790 | 21.0 |
| All others | 14,235 | 79.0 |
| Total lumber production, West Coast | 18,025 | 100.0 |

[1] Data provided by the three wholesale lumber firms on a nondisclosure basis.
[2] Data from directories of the forest industries published by The Lumberman and The Timberman, San Francisco, 1961.

Table 21. — Wholesale lumber market shares, total United States, 1959

| Item | Volume of lumber produced and/or shipped | Percent of market |
|---|---|---|
| | Million bd. ft. | |
| Three largest western wholesale lumber companies, total shipments[1] | 1,350 | 3.6 |
| Four largest producer-sellers, United States: | | |
| Weyerhaeuser Co.[2] | 1,300 | 3.5 |
| Potlatch Forests, Inc.[2] | 598 | 1.6 |
| Georgia-Pacific Corp.[2] | 539 | 1.4 |
| Boise Cascade Corp.[2] | 504 | 1.4 |
| Total, four largest producer-sellers | 2,941 | 7.9 |
| Total, above seven sellers | 4,291 | 11.5 |
| All others | 32,875 | 88.5 |
| Total lumber production, United States | 37,166 | 100.0 |

[1] Data provided by the three wholesale lumber firms on a nondisclosure basis.
[2]Data from directories of the forest industries published by The Lumberman and The Timberman, San Francisco, 1961.

The foregoing information on market shares of the three largest western wholesalers was developed by direct questions to each wholesale lumber firm. As a second source, information was developed from lists of cars rolling, taken from the offering lists of wholesale lumber firms. Most, but not all, cars of lumber sold by wholesalers will be represented in this list. The data shown in table 22 will therefore be less than the true volume sold by each wholesale firm. These additional estimates serve as a useful check against understatement of market shares developed in interviews.

Data are summarized for the Big Three in order to be comparable with tables 19, 20, and 21. In addition, the market shares of the Big Four wholesalers and the Big Eight are also shown. The data for the three largest firms shown for 1959 indicate a less significant market share than was developed through direct questions. The three largest firms shown in table 22 are the same as those questioned directly.

In addition, table 22 shows the relationship between the three largest firms and the next five. There is no single dominant firm in wholesaling as there is in resource ownership and lumber production. The relationship among wholesalers did not change in any significant manner between 1959 and 1960.

## Table 22. — Wholesale lumber market shares by region, 1959 and 1960

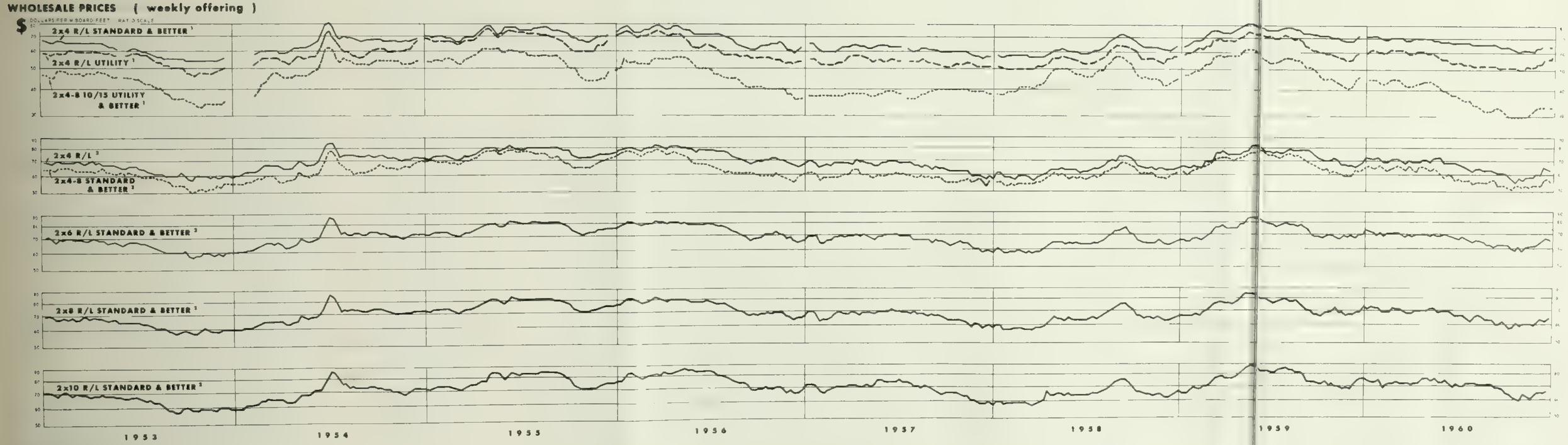
| Wholesale lumber company | 1960 | | | | | 1959 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cars rolling | Volume | Rank | Market shares | | Cars rolling | Volume | Rank | Market shares | | | |
| | | | | Douglas-fir subregion | United States | | | | Douglas-fir subregion | Pacific Northwest | Pacific coast | United States |
| | Number | Thousand bd. ft. | | — — Percent — — | | Number | Thousand bd. ft. | | — — — — — — — — Percent — — — — — — — — | | | |
| Oregon-Pacific Lumber Co. | 12,465 | 373,950 | 1 | 4.6 | 1.1 | 11,087 | 332,610 | 2 | 3.7 | 2.8 | 1.8 | 0.9 |
| Timberlane Lumber Co. | 10,223 | 306,690 | 2 | 3.8 | .9 | 11,499 | 344,970 | 1 | 3.8 | 2.9 | 1.9 | .9 |
| North Pacific Lumber Co. | 7,704 | 231,120 | 3 | 2.9 | .7 | 9,884 | 296,520 | 3 | 3.3 | 2.5 | 1.6 | .8 |
| Three largest firms[1] | 30,392 | 911,760 | -- | 11.3 | 2.7 | 32,470 | 974,100 | -- | 10.8 | 8.2 | 5.3 | 2.6 |
| Eugene-Willamette Lumber Co. | 6,144 | 184,320 | 4 | 2.3 | .6 | 5,379 | 161,370 | 4 | 1.8 | 1.3 | .9 | .4 |
| Four largest firms[1] | 36,536 | 1,096,080 | -- | 13.6 | 3.3 | 37,849 | 1,135,470 | -- | 12.5 | 9.4 | 6.3 | 3.0 |
| United Lumber Co., Inc. | 4,270 | 128,100 | 5 | 1.6 | .4 | 3,947 | 118,410 | 5 | 1.3 | 1.0 | .7 | .3 |
| Shamrock Lumber Co. | 3,273 | 98,190 | 6 | 1.2 | .3 | -- | -- | 10 | -- | -- | -- | -- |
| Vollstedt-Kerr Lumber Co. | 2,984 | 89,520 | 7 | 1.1 | .3 | 2,995 | 89,850 | 6 | 1.0 | .8 | .5 | .2 |
| Chapman Lumber Co., Inc. | 2,467 | 74,010 | 8 | .9 | .2 | 2,842 | 85,260 | 7 | .9 | .7 | .5 | .2 |
| Western Lumber, Inc. | -- | -- | 11 | -- | -- | 2,793 | 83,790 | 8 | .9 | .7 | .5 | .2 |
| Eight largest firms[1] | 49,530 | 1,485,900 | -- | 18.3 | 4.5 | 50,426 | 1,512,780 | -- | 17.0 | 12.6 | 8.4 | 4.1 |
| Total production for geographical area indicated | -- | -- | -- | Million bd. ft. 8,100 | Million bd. ft. 32,880 | -- | -- | -- | Million bd. ft. 9,104 | Million bd. ft. 11,962 | Million bd. ft. 18,025 | Million bd. ft. 37,166 |

[1] Largest for the Douglas-fir subregion.
Source: Developed from sales lists of cars offered by lumber wholesalers to potential customers

The facts presented above concerning economic concentration in wholesale lumber distribution show a highly competitive structure. The competitive structure in turn would clearly not allow monopolistic or oligopolistic exploitation of either the many lumber producers in the Douglas-fir subregion or the many who buy from wholesalers.

## Price Determination at the Wholesale Level

With a highly competitive structure in the production and wholesale distribution of lumber, one would expect to find competitive price behavior. Figure 5 shows a price series for three commonly traded lumber items as reported by "Random Lengths," a weekly market letter and price guide for the lumber industry. A second group of five lumber items is shown in figure 5 also. This latter series was developed from the weekly offering lists that one large western wholesaler mailed to prospective buyers. Both series show an extremely high degree of price flexibility characteristic of market-determined prices and in contrast to what has been termed "administered prices."




1 Source RANDOM LENGTHS a weekly journal letter Eugene Oregon

2 Source A western wholesale lumber company

Figure 5 — Wholesale prices, Douglas-fir lumber, 1953-60 (weekly offering prices)

Price determination at the wholesale level follows a standard procedure. First, both lumber producers and wholesalers send prospective buyers an offering list, usually on a weekly basis. The offering list identifies the species, grade, sizes, moisture condition, quantity, and price of lumber available. From this point on, most lumber is sold over the telephone. Relationships between wholesalers and their usual customers differ with the personalities involved. One wholesaler analyzed his telephone selling as follows: When a customer inquires about a given offer contained on the wholesaler's list and finds it still available, a price must be agreed upon. The starting point is the published offering price. This price becomes the agreed-upon price in approximately 50 percent of the cases. In the other 50 percent, bargaining produces a lower price. The prospective buyer may make an offer that usually varies between $0.50 and $2 per thousand board feet below the listed price. Approximately 25 percent of such offers are accepted. The other 75 percent is split between the price offered by the prospective buyer and the price listed by the wholesaler.

The prices shown in figure 5 should be interpreted in this light. They are offering prices. Actual prices, however, are made over the telephone. These frequently deviate from the offering price, and they are highly responsive to market conditions rather than being subject to price administration.[20] Therefore, actual prices are even more flexible than shown in the wholesaler offering list.

## Market-Determined Vs. Administered Prices

Lumber prices, being highly sensitive to changes in supply and demand (market determined), stand in sharp contrast to administered prices in some United States industries. The term "administered prices" was coined by Gardiner C. Means in 1935 and is defined as follows (U. S. Congress, 1935, p. 1):

> **There are two essentially different types of markets in operation — the traditional market in which supply and demand are equated by a flexible price and the administered market in which production and demand are equated at an inflexible administered price. In the first type of market, economic adjustments are brought about primarily by fluctuations in price. In the second type of market, economic adjustments are brought about primarily by changes in volume of production, while price changes are of secondary significance in producing adjustment. The difference between market prices and administered prices is clear. A market price is one which is made in the market as a result of the interaction of buyers and sellers**

[20] A similar situation exists in the textile industry. One study explained that the fact of little control over textile prices is "aggravated by the fact that most textile sales are made over the telephone." (See page 125 of: Backman, Jules, and Gainsbrugh, M. R. Economics of the cotton textile industry. 244 pp. New York: Natl. Indus. Conf. Board. 1946.)

> . . . . An administered price is essentially different. It is a price which is set by administrative action and held constant for a period of time. We have an administered price when a company maintains a posted price at which it will make sales or simply has its own prices at which buyers may purchase or not as they wish.

The period of time for which administered prices are held constant was not precisely defined. A 1939 National Resources Committee study directed by Means classified market-determined prices as those prices which change more than 77 times in an 8-year period and administered prices as those which change less than 23 times in the same period. Between these two extremes, approximately one-fourth of all items studied "are not clearly dominated by either the market or administration" (U. S. National Resources Committee, 1939, p. 110). Testifying before Congress in 1957, Means limited his commitment stating that "an administered price is set, and may be kept constant for weeks or months at a time" (U. S. Congress, 1957b, p. 75).

There are two essential elements in Means' definition of the administered price category which differentiate it from the market prices. First is the phenomenon of a price set by administrative action and held constant for weeks or months at a time. And second is the administrative reaction to a weak demand (perhaps during a recession) by production curtailments, thereby enabling prices to be maintained (or even increased).[21]

In order to show clearly the contrast between market-determined prices in the lumber industry and administered prices, figure 6 is presented showing monthly changes in wholesale prices for lumber and steel. Over the 92-month period for which price data are shown covering structural steel shapes, there were only eight price changes, averaging one price change per year. Of the eight price changes, all but one were price increases. The one price reduction was not significant, being only 0.2 percent. The price decline was so minor that it is not discernible in figure 6. Thus, the first element in Means' administered price definition, that of prices being held constant for a period of time, is clearly evident in the price of structural steel shapes. The opposite is true for lumber prices. Over the same period, lumber prices changed 89 times out of 92 possible occasions.

[21] In identifying administered prices, Means does not imply a value judgment: that they are "good" or "bad." He stated, "I want to say that administered prices are here and I do not regard administered prices as something that can or should be done away with. I regard them as an inevitable and indispensable part of our modern economy: As such, however, they are obviously something we should understand so that we may be able to take their effect into account in developing public policy. Administered prices present a way of doing business that leads to greater efficiency and higher standards of living. We could not have our big efficient department stores and mail-order houses if prices were not administered. Without this method of pricing, big efficient industry would find it almost impossible to operate. Administered prices are an essential part of our modern economy. The point of my testimony is rather that we do not know enough about how administered prices actually operate to be able to make good national policy in such economic fields as inflation, full employment, and enforcement of competition." (U. S. Congress, 1957b, p. 75).

## FLUCTUATIONS in PRICE and OUTPUT

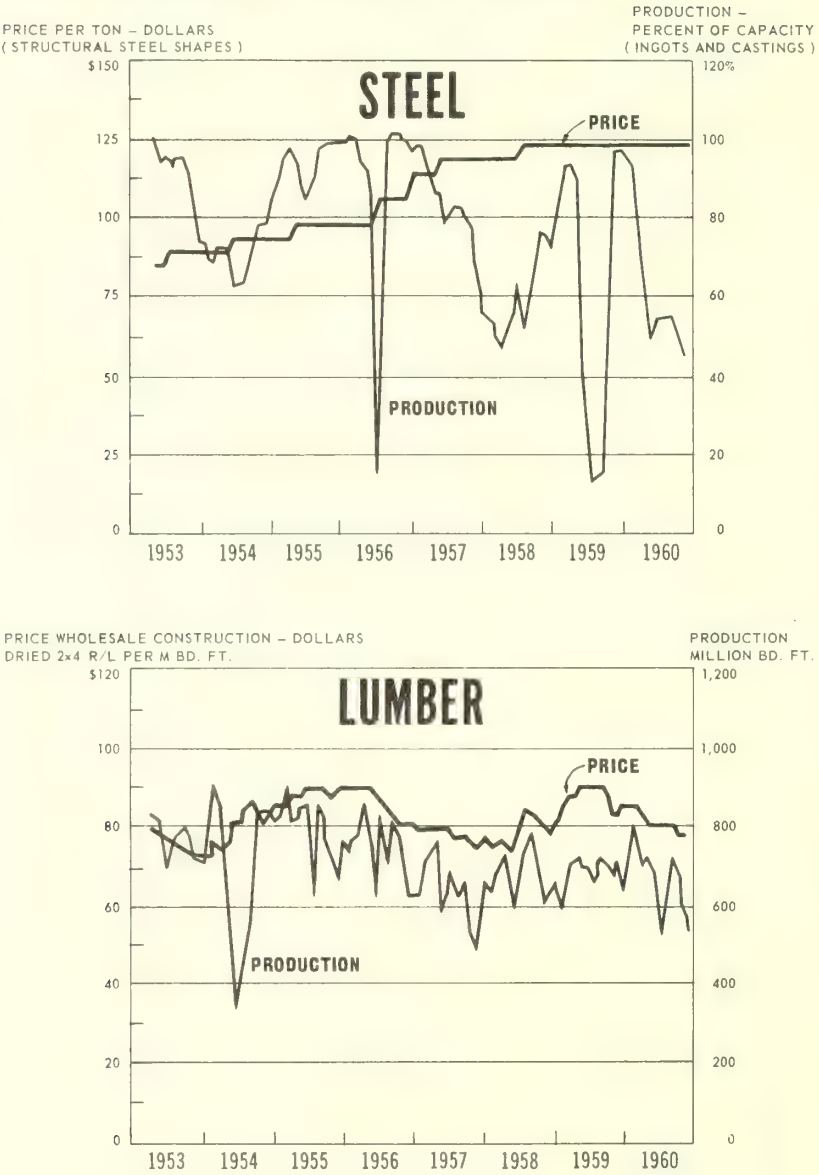



Figure 6. — Fluctuations in price and output — steel, 1953-60; lumber, 1953-60.

Also clearly evident in figure 6 is the second element of administered prices, that economic adjustments are brought about primarily by changes in the volume of production. In response to the 1953-54, 1957-58, and 1960-61 recessions, steel production was reduced to 63 percent, 48 percent, and 46 percent of capacity, respectively. By means of production curtailments, price responses (declines) were avoided. Contrary to the competitive response, steel prices were increased during the 1953-54 and 1957-58 recessions when there was abundant idle capacity. In the lumber industry, production curtailments are modest and are accounted for principally by marginal mills leaving the industry during periods of price weakness.

The price and output response shown for the lumber industry in figure 6 is precisely the kind of behavior that one would expect to follow from the competitive structure outlined in this study. The impressive merger movement notwithstanding, the industry remains sufficiently competitive in its structure so that no firm is able to restrict its output in a weak market and thereby prevent a price decline.

## Summary

The United States economy is subject to cycles of merger activity. The economy is currently in a post World War II merger revival period. Within the current merger wave the lumber industry has shown considerable merger activity, especially during the last half of the 1950's.

Examining the rationale for the current merger movement, we found that from the acquired firm's point of view the prime reason for selling out was an inability to compete in the open market for timber without the cost advantage of integration and diversification. The firm producing only lumber from its log input may be limited in its ability to bid for open market timber compared with some of its vertically integrated competitors. The latter are apparently able to develop much greater value from stumpage as a result of channeling logs into their optimum use and utilizing residual wood for pulp production.

The tax motive for selling out was found to be less important in the lumber industry than in other industries because capital gains tax treatment on income is available to operators processing their own timber. In contrast, the entrepreneur in most other industries must sell his firm in order to convert income from the ordinary income category to the capital gains category.

Receipt of an offer to merge which is high relative to its normal stock value appears in many cases to be a sufficient financial reason for merger, from the acquired firm's point of view. Illustrations are available showing that the value of a stockholder's investment may be increased from approximately 100 percent to approximately 500 percent by accepting the merger offer.

The desire to retire, together with an absence of successors or interested heirs to assume management responsibility, was a frequent reason given for selling. This management consideration was given more frequently in small firms than in large.

From the acquiring firm's point of view the principal motive for merger appears to be vertical integration. This motive is pursued as a means of profit maximization. The profit motive is enhanced when timber is involved due to the anticipation of capital gains tax treatment of profits from holding and growing timber. In this latter sense, the tax motive was found to be far more important in explaining mergers in the lumber industry, from the acquiring firm's point of view, than is true elsewhere in the U. S. economy.

The resource ownership structure of the Douglas-fir lumber industry has passed through several phases. As a result of the large land grants by Congress to the western railroads, a relatively high degree of concentration appeared by 1910. Two railroads, Southern Pacific and Northern Pacific, together owned 3,691,000 acres of timberland in Oregon and Washington. Weyerhaeuser Timber Co. had acquired nearly 2 million acres of timberland from the Northern Pacific Railroad. The four largest holders of timberland in 1910 owned 5,941,000 acres or 13.1 percent of all commercial forest land in Oregon and Washington. This had declined by 1953 to 3,714,000 acres held by the Big Four (not entirely the same four firms as in 1910) or 8.2 percent of the total and 19 percent of the privately owned commercial forest land in the two States. The Big Four of 1953 held only 63 percent as much timberland as the Big Four held in 1910.

From 1953 to 1960, however, the trend of economic concentration in resource ownership was reversed. Over this 7-year period in the Douglas-fir subregion the concentration ratio for the four largest firms increased from 22.4 percent to 26.2 percent. Thus, by 1960 the four largest firms owned more than one-fourth of all private commercial forest land in the Douglas-fir subregion. Concentration ratios for the eight largest firms increased from 27.4 percent to 34.1 percent of all private commercial forest land in the same period.

Relative to concentration ratios found in various manufacturing sectors of U. S. industry, economic concentration in resource ownership within the Douglas-fir subregion must be judged relatively low. However, concentration ratios in timberland ownership cannot be strictly compared to similar ratios in manufacturing. High concentration in the latter may be eroded away by new firms entering the industry and establishing new productive facilities. In contrast, new competition cannot enter timber resource ownership with equal ease. The amount of timberland can be increased only by converting land from other uses. With an expanding population, such conversions in large amounts seem highly improbable. In any case, nearly a lifetime must pass before a new timber crop will mature.

A further consequence follows from the present degree of concentration in resource ownership. Such concentration within small geographical supply areas of the Douglas-fir subregion carries with it possible concentrated advantages in bidding for open-market stumpage. Firms having a small reserve of private timber, or no reserves at all, may be placed at a substantial disadvantage in competing for timber.

On the other hand, there are potential welfare benefits for society resulting from large (in contrast to small) timberland ownerships. A Forest Service study of timberland management found that "large private owners, on the average, treat their lands better than the small owners." In another study, the Forest Service found that "productivity of recently cut areas on private lands is directly related to the size class of ownership — the smaller the ownership, the lower the proportion of recently cut land in the upper productivity class." Thus, there are both merits and demerits associated with the present trend toward blocking up timberland in large holdings.

Moving from economic concentration in resource ownership to concentration in lumber production, we find that the lumber industry in the United States is one of the most competitive industries in the entire economy. The four largest lumber producing firms in the Nation in 1954 accounted for only 6 percent of total lumber production. The 20 largest firms accounted for only 13 percent. When concentration ratios for the "sawmill and planing mill products" category are compared with concentration ratios for other industries competing for construction business, we find that lumber clearly has one of the most competitive structures found in the building materials industries. Of the 426 standard industry product classes (4-digit) listed for U. S. manufacturing industries, only 5 have lower concentration ratios for the four largest companies than is found for the "sawmill and planing mill products" class. In terms of the 8 largest firms and 20 largest

firms, only two product classes have lower concentration ratios than "sawmill and planing mill products." This very highly competitive structure existed in 1954 in spite of the merger movement in the lumber industry.

Over a long period of time, it was found that concentration declined from 1929 to 1947 and increased from 1947 to 1960. In the latter period, however, the share of total output produced by large mills was considerably lower than in 1929.

Similarly, within the Douglas-fir segment of the lumber industry a highly competitive structure is found. In 1960, the four largest lumber producers in the Douglas-fir subregion accounted for only 23.9 percent of total subregion lumber production. The 20 largest firms accounted for 40.6 percent of the subregion's lumber production.

From 1947 to 1954, concentration ratios in Douglas-fir lumber production increased only modestly. The market share of the four largest firms increased from 15.9 percent in 1947 to 16.6 percent in 1954. The current merger movement produced its major effects on the lumber industry from 1954 to 1960. The Big Four market share increased from 16.6 percent to 23.9 percent in this 6-year period.

Preoccupation with the large producers in the Douglas-fir lumber industry should not obscure the dynamic changes taking place in the small-firm category. The most significant change in the structure of the Douglas-fir lumber industry in recent years is clearly the mass exodus of small mills from the industry. In 1948 there were 1,675 mills in the Douglas-fir subregion. Twelve years later 78 percent of these mills had stopped production, leaving only 291 small mills in operation. The small mills did not disappear from the industry as a result of merger activity, but as a result of the relatively weak lumber market prevailing through most of the 1950's and the inability of the nonintegrated firms to compete for open-market stumpage. The mass exodus of mills under deteriorating profit conditions is an offset to the mass entry of mills during the increasingly profitable period 1933 to 1948. The number of firms leaving the industry in the post-1948 period is almost exactly equal to the number of entrants during the pre-1948 period.

Wholesale lumber distribution from the Douglas-fir lumber industry is similarly characterized by a highly competitive structure. There are a multitude of wholesale and commission firms performing a middleman function. There are no significant barriers to entry. The three largest western wholesale lumber firms handle only 14.8 percent of total Douglas-fir subregion lumber production. In addition, the four largest lumber producers

are also wholesalers of their product. They produce and market another 21.5 percent of total subregion production. Thus, the seven largest sellers of lumber account for not more than 36.3 percent of total Douglas-fir subregion production. Since part of the production of the four largest lumber producing firms is distributed through the three largest wholesalers, the market share of the seven largest sellers would be less than the 36.3 percent indicated above.

The behavior of wholesale lumber prices reflects the highly competitive structure of the industry. There is an extremely high degree of price flexibility demonstrated on a weekly or monthly basis. Wholesalers offer lumber at prices advertised by weekly mailings to prospective customers. However, the market price is arrived at by means of telephone conversations, and the price is highly responsive to rapid changes in supply and demand expectations.

Lumber prices are clearly market determined. They move upward with market strength and downward with market weakness. Market-determined lumber prices may be compared to administered prices for the steel industry. In the latter case, prices are fixed for long periods of time. There are few producers in the steel industry. The industry is characterized as oligopolistic. Output of steel is adjusted downward in periods of weak demand so that price may be maintained. In several instances, steel prices were increased though the industry was operating at only about half capacity. In contrast, when lumber demand declines, prices fall and marginal mills are forced out of production. While resulting reduction in output is modest compared with the steel industry, price declines are significant. The price and output behavior of lumber is characteristic of the highly competitive structure that has been outlined in this study.

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# Improved Procedure

# for CALCULATING STREAM DISCHARGE

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February 1964

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
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FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

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## INTRODUCTION

Stream discharge (the volume of water passing a point in a stream during a specified interval of time) is frequently calculated from a hydrograph which relates head (i.e., water depth) to time. At any instant of time, the rate of flow can be computed by a formula which for many weirs takes the form

$$q = aH^b \quad [1]$$

where q = cubic feet per second

H = head, or depth of water (feet) in the weir

a and b = constants depending on characteristics of the weir.

With q thus available for each instant of time, the problem is to calculate discharge for any interval of time.

In the interest of simplicity, discharge is normally calculated by one of several approximate procedures.[1/] The precise procedure to be developed here is also reasonably simple, and the calculations can be performed on desk calculators without excessive difficulty If electronic data processing machines are available, the precise procedure is certainly the recommended one.

## CALCULATION PROCEDURE

### Step 1

Mark the hydrograph so that the relation of head (H) to time (t) is linear between consecutive marks.

---

1/ Johnson, Edward A., and Dils, Robert T. Outline for compiling precipitation, runoff, and groundwater data from small watersheds. U.S. Forest Serv. Southeast. Forest Expt. Sta. Sta. Paper 18, 40 pp., illus. 1956.

Step 2

For each linear segment on the hydrograph tally beginning time ($t_1$) and corresponding head ($H_1$), and ending time ($t_2$) and head ($H_2$).

Step 3

Calculate discharge (Q) for each linear segment with the following formulas

(a) when $H_2 \neq H_1$

$$Q = \frac{a}{b+1} \cdot \frac{t_2 - t_1}{H_2 - H_1} \left( H_2^{b+1} - H_1^{b+1} \right) (3600) \quad [2]$$

(b) when $H_2 = H_1$

$$Q = aH^b (t_2 - t_1) (3600) \quad [3]$$

where Q = cubic feet and 3600 = number of seconds in an hour

Example

Water is flowing through a right-angled V-notch weir characterized by a discharge formula

$$q = 2.52H^{2.47}$$

Preliminary analysis of the hydrograph established a linear segment between 9 a.m. and 9.30 a.m., at which times the corresponding heads were 0.25 and 0.30 foot. Thus:

| | | |
|---|---|---|
| $a = 2.52$ | $t_1 = 9.0$ | $H_1 = 0.25$ |
| $b = 2.47$ | $t_2 = 9.5$ | $H_2 = 0.30$ |

From equation 2,

$$Q = \frac{2.52}{3.47} \frac{(9.5-9.0)}{(0.30-0.25)} (0.30^{3.47} - 0.25^{3.47}) (3600)$$

$$= 188 \text{ cubic feet.}$$

In practice, the calculations would not be as formidable as indicated above. For a given weir, the ratio $\frac{a(3600)}{b+1}$ remains a constant, and the values of $H^{3.47}$ would be obtained from tables rather than calculated individually.

## Development of Equation 2

The basic integral leading to equation 2 is

$$Q = \int_{t_1}^{t_2} aH_i^b \, dt \qquad [4]$$

If this integral is restricted in application to a linear segment of the head-time hydrograph, so that

$$H_i = H_1 + K(t_i - t_1) \qquad [5]$$

$$\text{where } K = \frac{H_2 - H_1}{t_2 - t_1}$$

Then equation 4 may be written

$$Q = a \int_{t_1}^{t_2} \left[H_1 + K(t_i - t_1)\right]^b dt \qquad [6]$$

and evaluated as

$$Q = \frac{a}{b+1}\,\frac{t_2 - t_1}{H_2 - H_1}\left[\left[H_1 - \left(\frac{H_2 - H_1}{t_2 - t_1}\right)(t_2 - t_1)\right]^{b+1} - \left[H_1 - \left(\frac{H_2 - H_1}{t_2 - t_1}\right)(t_1 - t_1)\right]^{b+1}\right]$$

$$= \left(\frac{a}{b+1}\right)\left(\frac{t_2 - t_1}{H_2 - H_1}\right)\left(H_2^{\,b+1} - H_1^{\,b+1}\right) \quad \ldots [7]$$

If H is expressed in feet and t in hours, then equation 7 must be multiplied by 3600 (the number of seconds in an hour) to obtain the total discharge in cubic feet

## COMPARISON OF METHODS

Table 1 shows that discharge as calculated by commonly accepted methods may yield values considerably greater than those calculated by the integration method For this illustration, the average rate method was used, in which

$$Q = \left[\frac{aH_1^{\,b} - aH_2^{\,b}}{2}\right](t_2 - t_1)$$

and the calculations are for a right-angled V-notch weir with a rating formula $q = 2.52H^{2.47}$

Figure 1 illustrates the fact, for a linear segment of the hydrograph, that discharge by the integration method is always less than the value obtained by other methods. During period AB discharge rate q varies along curve EFC. The integration method evaluates the area under curve EFC. In contrast, the average-rate method averages discharge rates at times A and B, and perforce evaluates the area under line EDC

Table 1 --Comparison of discharge by the integration and average-rate methods

| Variable | Unit | Example | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| $Q_a$ [1/] | Cu ft. | 946 | 973 | 1,290 | 1,756 |
| $Q_b$ [2/] | Cu ft | 946 | 972 | 1,272 | 1,677 |
| $Q_a - Q_b$ | Cu ft, | 0 | 1 | 18 | 79 |
| | | Basis for computations | | | |
| $H_1$ | Feet | 0.400 | 0.40 | 0.40 | 0.40 |
| $H_2$ | Feet | 0.401 | 0.41 | 0.50 | 0.60 |
| $t_2 - t_1$ | Hours | 1.00 | 1.00 | 1.00 | 1.00 |
| dH/dt | Ft./hrs | 0.001 | 0.01 | 0.10 | 0.20 |

1/ $Q_a$ Discharge by the average-rate method

2/ $Q_b$ Discharge by the integration method

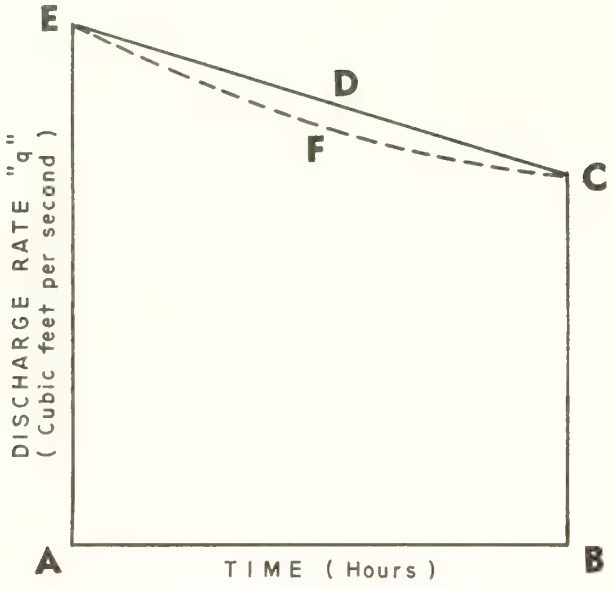


Figure 1.--Representation of stream discharge as calculated by commonly accepted methods (area ABCDE) and by the integration method (area ABCFE).

Discharge as evaluated by approximate procedures will approach the correct value if the time span between hydrograph readings is shortened so as to reduce to a minimum the difference in head. Example A, table 1, shows that with a difference in head of only 0.001 foot, the two computational methods yield the same discharge figures. The advantage of the integration method is that any time span may be utilized as long as the rate of change in head remains uniform. Thus, the true discharge will be obtained from a smaller number of hydrograph readings and with considerably reduced labor.

Bethlahmy, Nedavia
1964. Improved procedure for calculating stream discharge. U S. Forest Serv. Res. Paper PNW-10, 6 pp., illus.

An integration method for computing discharge more accurately with fewer hydrograph readings.

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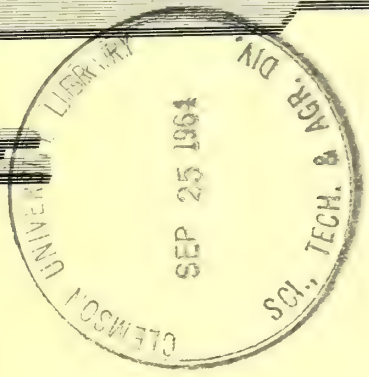
# FOREST INDUSTRY CAPACITY, PRODUCTION and AVAILABLE LOG SUPPLIES

## *in the Douglas-Fir Subregion*

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**U.S. DEPARTMENT OF AGRICULTURE**

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# FOREST INDUSTRY CAPACITY, PRODUCTION, AND AVAILABLE LOG SUPPLIES IN THE DOUGLAS-FIR SUBREGION

by

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# FOREWORD

Until the time of World War II, the forest industries of the Douglas-fir subregion in the States of Oregon and Washington enjoyed a relative abundance of log supplies. Since World War II, however, log supply has generated critical problems for many wood-using plants in the subregion. Average stumpage prices for Douglas-fir timber, for example, increased from less than $10 per thousand board feet in 1947 to more than $30 per thousand board feet in 1959 and 1960. Lumber realization in the Douglas-fir subregion, on the other hand, after increasing to $80.50 in 1951, declined to $75.01 in 1960. One response to this situation was an increase in pressure to raise the allowable cut on public lands and to intensify timber management in order to sustain existing installed capacity.

This study was undertaken to develop a better understanding of the changing forest industry complex in the Douglas-fir subregion in relation to the log supply situation. It studies trends and relationships in forest industry capacity, production, and available log supplies and examines the outlook and prospective problems of log supply and plant adjustments in the subregion.

Information on capacity and production is presented separately for the lumber, plywood, and pulp industries. Total capacity of these forest industries is then compared with total log production and with the prospectively available log supplies indicated by the allowable cut plans of public forestry agencies and by projections of available log supplies from private timberlands.

Trends and relationships are shown for the subregion as a whole and separately for four subareas as follows:

WASHINGTON

Puget Sound (composed of Clallam, Island, Jefferson, King, Kitsap, Lewis, Mason, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom Counties)

Southwestern Washington (composed of Clark, Cowlitz, Grays Harbor, Pacific, Skamania, and Wahkiakum Counties)

OREGON

Northwestern Oregon (composed of Benton, Clackamas, Clatsop, Columbia, Hood River, Lincoln, Linn, Marion, Multnomah, Polk, Tillamook, Washington, and Yamhill Counties)

Southwestern Oregon (composed of Coos, Curry, Douglas, Jackson, Josephine, and Lane Counties)

Since this study was completed, the author, Dr. John Fedkiw, was transferred to the Washington, D. C., office of the Forest Service.

Carl A. Newport, Chief

Division of Forest Economics and
Marketing Research

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# The Lumber Industry

Before World War II, 80 percent or more of the log production of the subregion was consumed by the lumber industry. After 1955, however, lumber was only able to command 65 percent of the log output. Unused sawmill capacity became a prevalent issue for much of the lumber industry in the decade of the 1950's.

## Definition and Estimation of Plant Capacity

Annual plant capacity in this report is defined as the maximum practicable lumber output that might be obtained from installed plant and equipment, assuming availability of timber, labor, and other production factors and the typical shifts operated by the industry in periods of favorable market demand.

Available information on plant capacity in the lumber industry of the Douglas-fir subregion is not exact, complete, or precisely comparable from year to year. Accordingly, the estimates compiled for this report must be considered as subject to some interpretation.

Estimates of annual capacity are presented in the last column of table 1. They were derived by applying the following expansion factors to the total reported daily capacity of sawmills as tabulated in the second column of table 1:

| | |
|---|---|
| 1929-34 | 300[1] |
| 1935-39 | 250[1] |
| 1940-60 | 240 |

[1] Factors used in this report for the period 1929 to 1939 are derived from the footnotes, p. 31, of "The Douglas Fir Lumber Industry," Bur. Res. Statis., Advisory Comm., Council Natl. Defense. 98 pp. 1941.

The factor 240 is the average ratio of reported annual production to reported daily capacity during the 3 years 1942 to 1944 when utilization of daily sawmill capacity was at the highest consistent level for the period 1940-60. The expansion factor 240 is an average for the industry. Factors for individual mill size classes have been estimated to be as follows:

| Mill size class, daily capacity (Board feet) | Average days operated per year (Number) |
|---|---|
| 0- 39,999 | 160 |
| 40,000- 79,999 | 220 |
| 80,000-119,999 | 250 |
| 120,000+ | 280 |

These were derived by relating reported daily capacity to the annual production of each size class during the years 1948 to 1958. Within each mill size class there is considerable variation in days operated by individual mills.

Table 1. — Estimated sawmill capacity in the Douglas-fir subregion, 1929-60

| Year | Active and idle mill capacity | |
|---|---|---|
| | Daily | Annual |
| | Thousand board feet | Million board feet |
| 1929 | 39,740 | 11,922 |
| 1930 | 38,768 | 11,630 |
| 1931 | -- | -- |
| 1932 | 33,066 | 9,920 |
| 1933 | 32,267 | 9,680 |
| 1934 | 33,404 | 8,351 |
| 1935 | -- | -- |
| 1936 | 34,409 | 8,602 |
| 1937 | 36,432 | 9,108 |
| 1938 | 35,279 | 8,820 |
| 1939 | -- | -- |
| 1940 | 35,809 | 8,952 |
| 1941 | 37,939 | 9,105 |
| 1942 | 37,688 | 9,045 |
| 1943 | 37,427 | 8,982 |
| 1944 | 34,560 | 8,294 |
| 1945 | -- | -- |
| 1946 | 37,783 | 9,068 |
| 1947 | 43,202 | 10,368 |
| 1948 | 44,936 | 10,785 |
| 1949 | 45,165 | 10,840 |
| 1950 | 45,922 | 11,021 |
| 1951 | 50,161 | 12,039 |
| 1952 | 49,583 | 11,900 |
| 1953 | 47,098 | 11,304 |
| 1954 | 46,364 | 11,127 |
| 1955 | 47,858 | 11,486 |
| 1956 | 44,530 | 10,687 |
| 1957 | 42,785 | 10,268 |
| 1958 | 40,527 | 9,726 |
| 1959 | 39,724 | 9,534 |
| 1960 | 39,431 | 9,464 |

Source: Daily capacity from directories of the forest industries, published by The Lumberman and The Timberman, Portland, Oreg.

The figures for daily capacity for the period 1929-60 were derived by summing the daily capacity of sawmills listed in the directories of the forest industries published annually by The Lumberman and The Timberman. These listings were corrected for obvious inconsistencies between years and for omissions in the case of a few larger mills whose capacities were otherwise known.

The daily capacity listed in the directories is for one or more shifts as reported by each mill. The listings included idle mills without differentiation from active mills and also mills for which no capacity was reported. The latter, for the most part, were the very smallest mills and no capacity was estimated for them in table 1. Mills reported out of business were excluded.

## Relationships in the Subregion

### Sawmill Capacity and Lumber Production Show Wide Fluctuations

Figure 1 and table 2 show annual sawmill capacity and annual lumber production between 1925 and 1960. Changes in reported capacity generally have followed the broad movements in the lumber market. When lumber production was at its peak levels of 10.3 and 10.4 billion board feet respectively in 1929 and 1952, capacity likewise was at a peak level, 11.9 billion board feet in both 1929 and 1952. Between the peak production years, capacity fell to a low level of about 8.8 billion feet from 1934 to 1944. Production, however, dropped more, reaching a low of 3.2 billion feet in 1932 and averaging 5.8 billion feet between 1930 and 1940.

Table 2. — Annual capacity and production of the lumber industry in the Douglas-fir subregion, 1925-60

| Year | Lumber production | Capacity | Unused Capacity | |
|---|---|---|---|---|
| | | | Amount | Percent of capacity |
| | MM bd. ft. | MM bd. ft. | MM bd. ft. | |
| 1925 | 9,514 | -- | -- | -- |
| 1926 | 10,285 | -- | -- | -- |
| 1927 | 9,902 | -- | -- | -- |
| 1928 | 10,109 | -- | -- | -- |
| 1929 | 10,290 | 11,922 | 1,632 | 14 |
| 1930 | 7,681 | 11,630 | 3,949 | 34 |
| 1931 | 5,401 | -- | -- | -- |
| 1932 | 3,153 | 9,920 | 6,767 | 68 |
| 1933 | 4,348 | 9,680 | 5,332 | 55 |
| 1934 | 4,396 | 8,351 | 3,955 | 47 |
| 1935 | 5,113 | -- | -- | -- |
| 1936 | 6,838 | 8,602 | 1,764 | 21 |
| 1937 | 7,067 | 9,108 | 2,041 | 22 |
| 1938 | 5,510 | 8,820 | 3,310 | 38 |
| 1939 | 6,945 | -- | -- | -- |
| 1940 | 7,589 | 8,952 | 1,363 | 15 |
| 1941 | -- | 9,105 | -- | -- |
| 1942 | 9,058 | 9,045 | -13 | 0 |
| 1943 | 8,664 | 8,982 | 318 | 4 |
| 1944 | 8,496 | 8,294 | -202 | -2 |
| 1945 | 6,586 | -- | -- | -- |
| 1946 | 7,835 | 9,068 | 1,233 | 14 |
| 1947 | 8,962 | 10,368 | 1,406 | 14 |
| 1948 | 9,405 | 10,785 | 1,380 | 13 |
| 1949 | 9,135 | 10,840 | 1,705 | 16 |
| 1950 | 10,108 | 11,021 | 913 | 8 |
| 1951 | 9,850 | 12,039 | 2,189 | 18 |
| 1952 | 10,364 | 11,900 | 1,536 | 13 |
| 1953 | 9,745 | 11,304 | 1,559 | 14 |
| 1954 | 9,283 | 11,127 | 1,844 | 17 |
| 1955 | 9,662 | 11,486 | 1,824 | 16 |
| 1956 | 8,759 | 10,687 | 1,928 | 18 |
| 1957 | 7,952 | 10,268 | 2,316 | 23 |
| 1958 | 8,439 | 9,726 | 1,287 | 13 |
| 1959 | 9,104 | 9,534 | 430 | 5 |
| 1960 | 8,029 | 9,464 | 1,435 | 15 |

Source: Lumber production data from West Coast Lumbermen's Association.

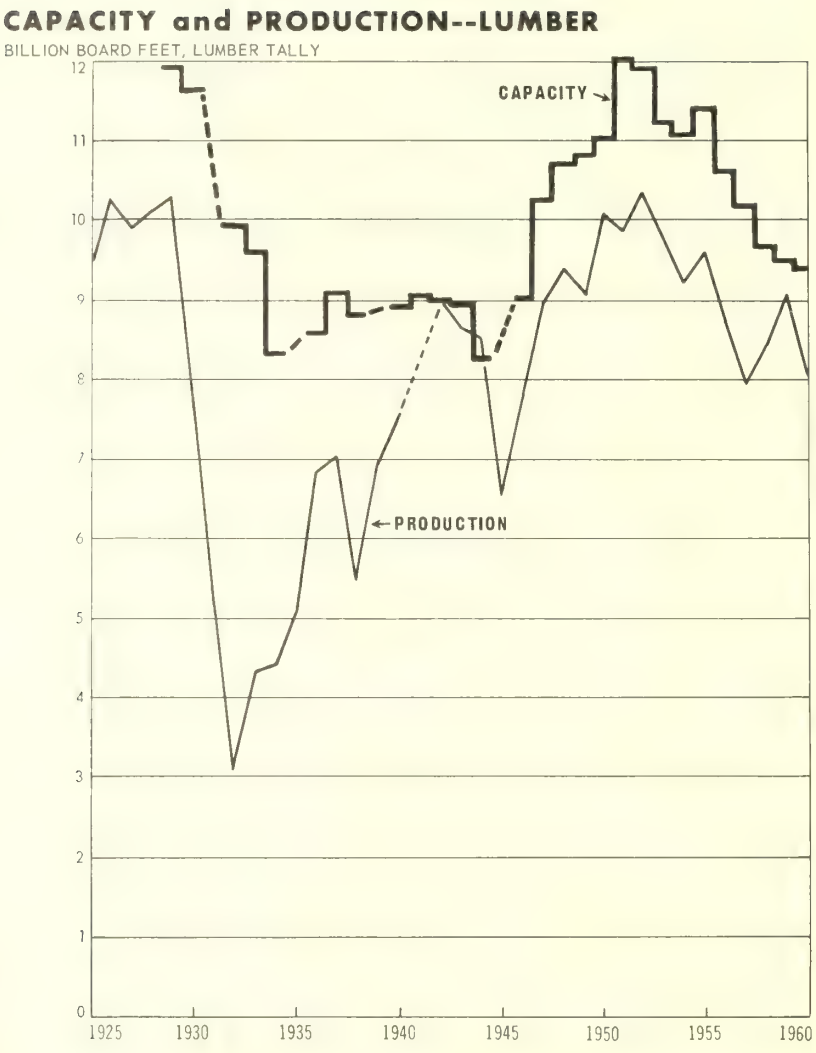


Figure 1. — Annual capacity and production of the lumber industry in the Douglas-fir subregion, 1925-60.

After the postwar peak in lumber production in 1952, the lumber industry of the Douglas-fir subregion adjusted its capacity downward by 2,576 million board feet.[1] Lumber capacity in 1960 was 9,463 million feet. In the same period, production declined from the high level of 10,017 million board feet in the years 1950-53 to an average level of 8,381 million feet in the years 1957-60.

## Unused Capacity a Persistent Characteristic

During the great depression of the 1930's, the lumber industry's capacity was reduced but not nearly as much as its production. For some years after 1929, there was considerable unused capacity relative to the market. Unused capacity averaged more than 40 percent through 1934. Then, and until 1940 when it dropped to 15 percent, it varied between 21 and 38 percent.

During World War II, lumber capacity in the subregion was rather fully utilized. In the following years, when the national lumber market expanded to meet the demands of the postwar building boom, capacity increased more than production. From 1952 to 1960, the industry carried an average unused capacity of 15 percent or 1.6 billion board feet. In 1959, unused capacity was at the lowest level since the end of the war, partly because of the high level of production in that year and partly because of the reduction in capacity that had taken place in the preceding years. In 1960, however, when the lumber market was down, unused capacity was again up to a high level of 1.4 billion board feet.

## Capacity Changes Related to Prices and Earning Rates

The rapid postwar expansion of lumber capacity in the Douglas-fir subregion was directly associated with the rise in lumber prices and earning rates. From 1938 to 1946, average lumber realization value increased from $19.14 to $45.48 per thousand board feet — 11.4 percent per year.[2] From 1946 to 1951, lumber realization value increased 12.1 percent per year to $80.50.

Up to 1947, the sharp rise in lumber price was accompanied by a rapid increase in the apparent earning rate in the Douglas-fir lumber industry.[3] It increased from 7.8 percent in 1938 to a high of 32.7 percent

[1] The gross reduction exceeded 3 billion board feet. This was offset in part by new construction as the center of lumber production shifted southward to southwestern Oregon and by continued expansion of capacity of mills with an output of 80,000 to 119,999 board feet per day while capacity in other mill size classes declined.

[2] From West Coast Lumbermen's Association "Industrial Facts," published monthly, Portland, Oreg.

[3] Based on average lumber realization and average cost as reported by the West Coast Lumbermen's Association. These data do not provide a precise measure of profits of the lumber industry in the Douglas-fir subregion. It is assumed, however, that the difference between average realization and average cost is correlated with net earnings. The difference expressed as a percent of average realization is herein referred to as the apparent earning rate.

in 1947. From 1946 to 1951, the apparent earning rate averaged 24 percent. In the same period, capacity increased 3.0 billion board feet while production increased 2.0 billion feet. After 1951, the apparent earning rate, capacity, and production all declined while average costs continued to rise, as can be seen from figure 2.

## Competitive Strength of Lumber Declines During Expansion of Capacity

During the postwar expansion of lumber capacity, average lumber realization values and prices in the Douglas-fir subregion rose more than the wholesale prices of other building materials. From 1938 to 1951, the wholesale price index of construction materials increased only 7.4 percent[4] per year, compared with an 11.7 percent per year increase in average realization for the subregion's lumber output. The tremendous inflation of lumber prices to 1951 tended to reduce the competitive strength of lumber in the building materials market. The relative price behavior of lumber from the subregion and selected competing materials is illustrated in figure 3.

After 1951, the wholesale price index for all commodities rose some 0.5 percent per year, while the wholesale price index for construction materials rose about 1.1 percent per year. Average lumber realization values for the Douglas-fir subregion, on the other hand, declined an average of 0.7 percent per year.

These trends tended to restore somewhat the competitive strength of lumber from the Douglas-fir subregion relative to other construction materials, but not enough to halt the downward trend in production at the same time.

## Western Lumber Production Expands as Douglas-fir Subregion's Declines

From 1946 to 1960, lumber production in the Western States expanded 34 percent as shown in figure 4. Lumber production in the Douglas-fir subregion, however, rose from about 8 billion board feet in 1946 to 10.4 billion board feet in 1952, and then dropped back to about 8 billion feet in 1960. The steady rate of growth in lumber production in the balance of the Western States not only was sufficient to offset the substantial decline in the Douglas-fir subregion since 1952, but was also great enough to expand the total output of the Western States to a new high level of 22 billion feet in 1959.

[4] Table 8, p. 41 of: U. S. Forest Service and Agricultural Stabilization and Conservation Service. The demand and price situation for forest products. 47 pp., illus. 1961.

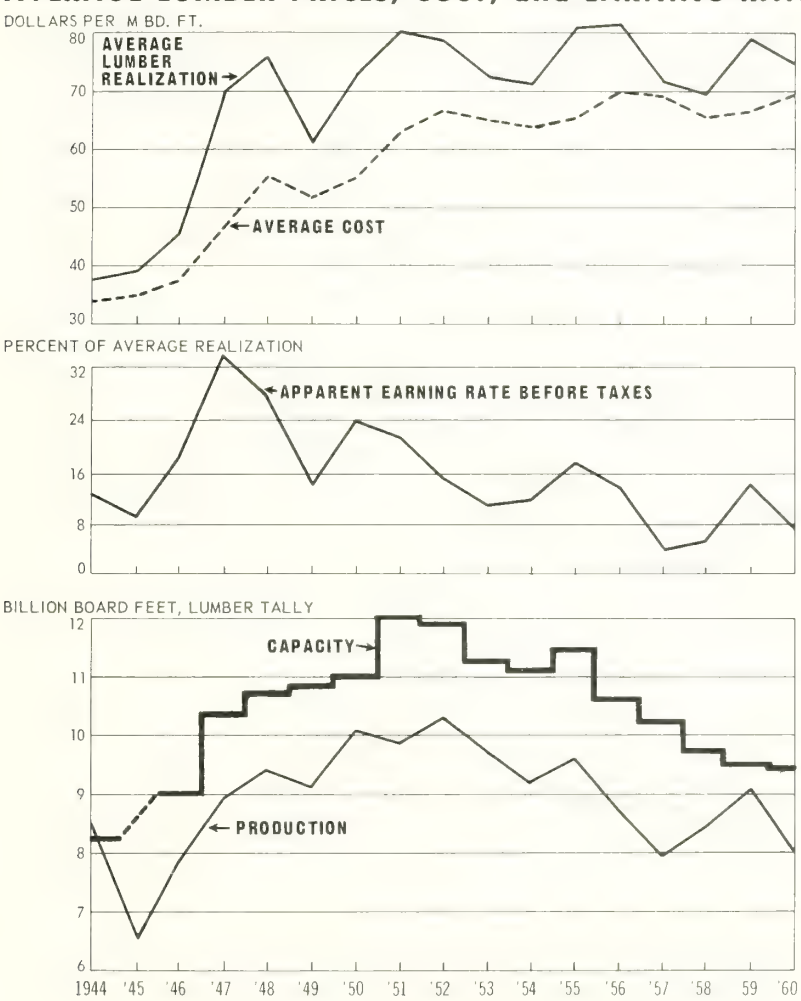


Figure 2. — Relationship of capacity and production to lumber prices and apparent earning rate before taxes.

## WHOLESALE PRICE INDEX FOR LUMBER and OTHER MATERIALS

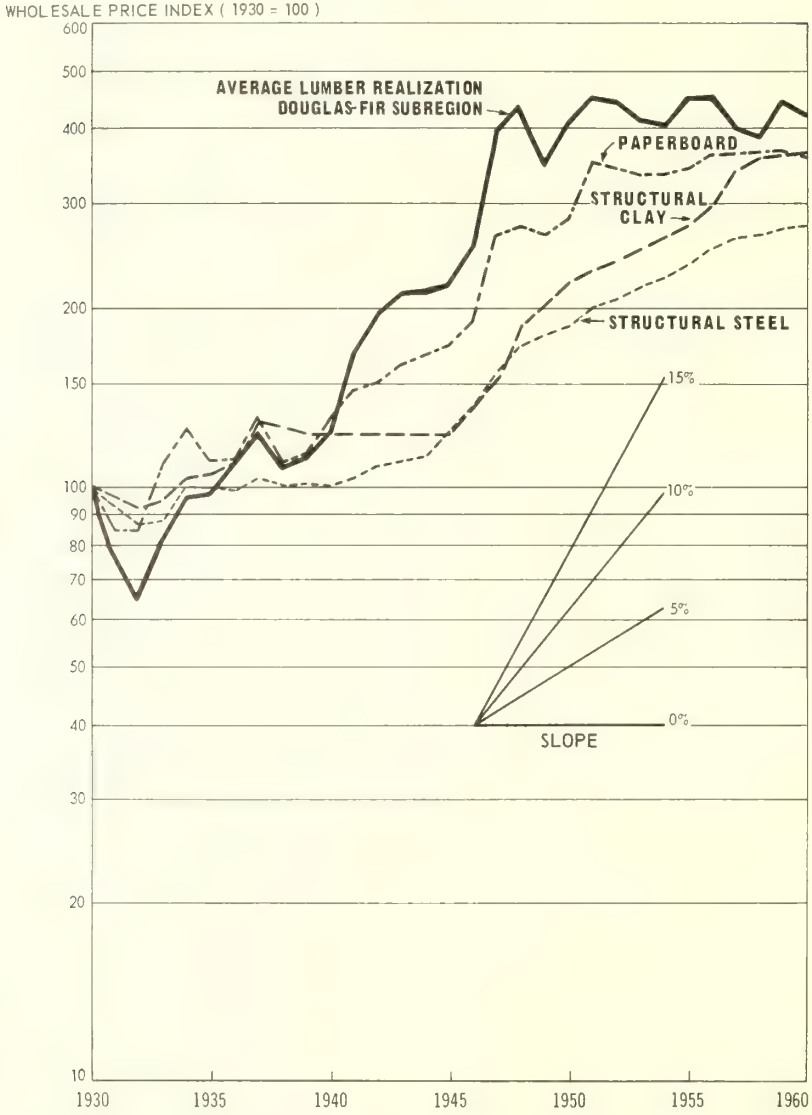


Figure 3. — Trend of wholesale price index for lumber and selected construction materials, 1930-60.

Sources: Table 8, adapted to 1930 = 100, from "The Demand and Price Situation for Forest Products." U. S. Forest Serv. and Agr. Stabilization Conserv. Serv., 47 pp., illus. 1961. Average lumber realization of Douglas-fir subregion from West Coast Lumbermen's Association "Industrial Facts," published monthly, Portland, Oreg.

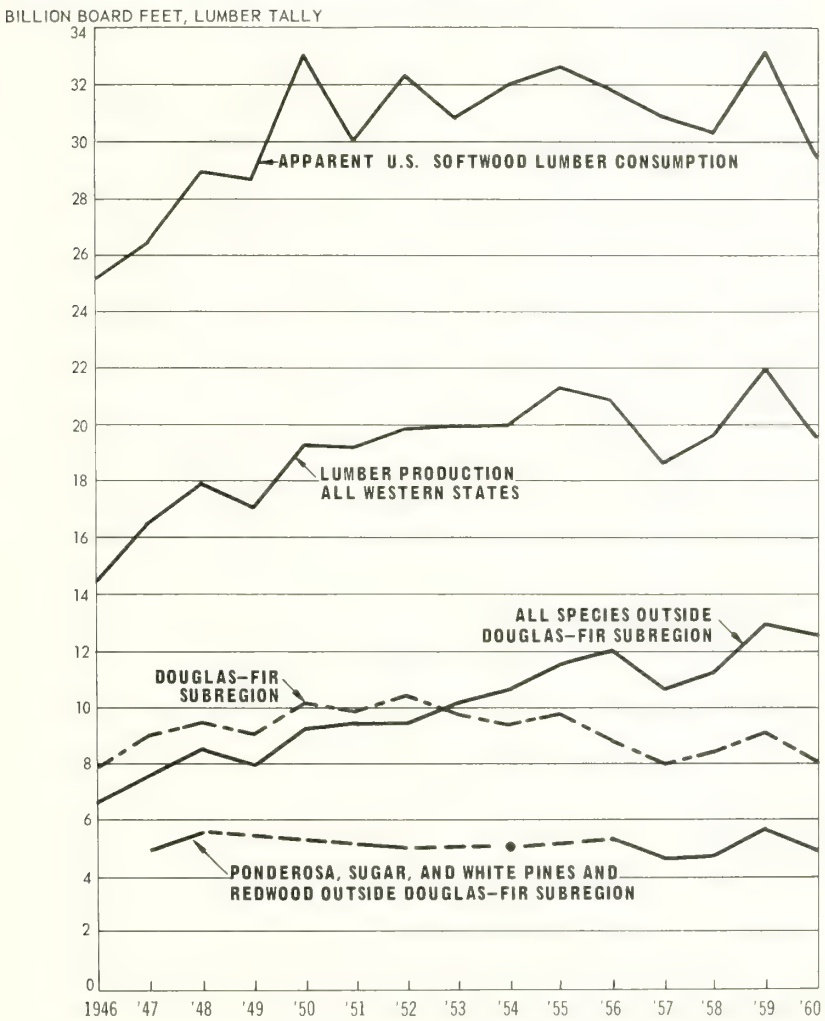


Figure 4. — Trends in western lumber production and apparent U. S. softwood lumber consumption, 1946-60.

Apparent U. S. lumber consumption remained more or less stable after 1950, averaging 31.7 billion feet to the end of the decade, with an average deviation of only 3.1 percent. Lumber production in the Western States, on the other hand, increased its share of U. S. softwood consumption from 58 percent in 1950 to 66 percent in 1960. The share of the Douglas-fir subregion, however, declined from about 31 percent in 1950 to 27 percent in 1960.

## Relationships in Subareas

### Western Washington's Sawmill Capacity Shows Steady Decline Since 1929

From 1929 to 1960, the annual sawmill capacity in western Washington declined 4.6 billion board feet. Production declined sharply from 1929 to 1932, recovered somewhat during the war years, then dropped again to less than 2.5 billion feet in 1960. As can be seen from figure 5, the heaviest losses in capacity and production in this period occurred in the Puget Sound area.

After 1952, both lumber capacity and lumber output declined, with capacity steadily adjusting more closely to actual production. From 1955 to 1960, however, the unused capacity still averaged about 13 percent of total capacity. Most of the excess was concentrated in the Puget Sound area, where it averaged about 333 million feet or 18 percent per year. In southwestern Washington, on the other hand, capacity and output have been closely adjusted since 1940. There the average unused capacity from 1955 to 1960 was only 30 million feet, or 3 percent.

In 1960, however, unused capacity in western Washington was 500 million feet, or 17 percent.

### Western Oregon's Sawmill Capacity Shows Large Increase Since 1929

After 1929, western Oregon's sawmill capacity declined to a low of 3.5 billion feet in 1932 and then slowly recovered during the balance of the 1930's. In 1942, its capacity exceeded western Washington's for the first time, and as the lumber industry continued to shift from Washington to Oregon, western Oregon's capacity rose to a peak of 8.4 billion feet in 1951. In the next 3 years, Oregon's capacity declined to 7.9 billion feet, as can be seen from figure 5, but in 1955 it was again up to 8.4 billion as expansions in southwestern Oregon temporarily offset declines in northwestern Oregon. After 1955, however, western Oregon's capacity dropped abruptly, reaching a low of 6.6 billion feet in 1960.

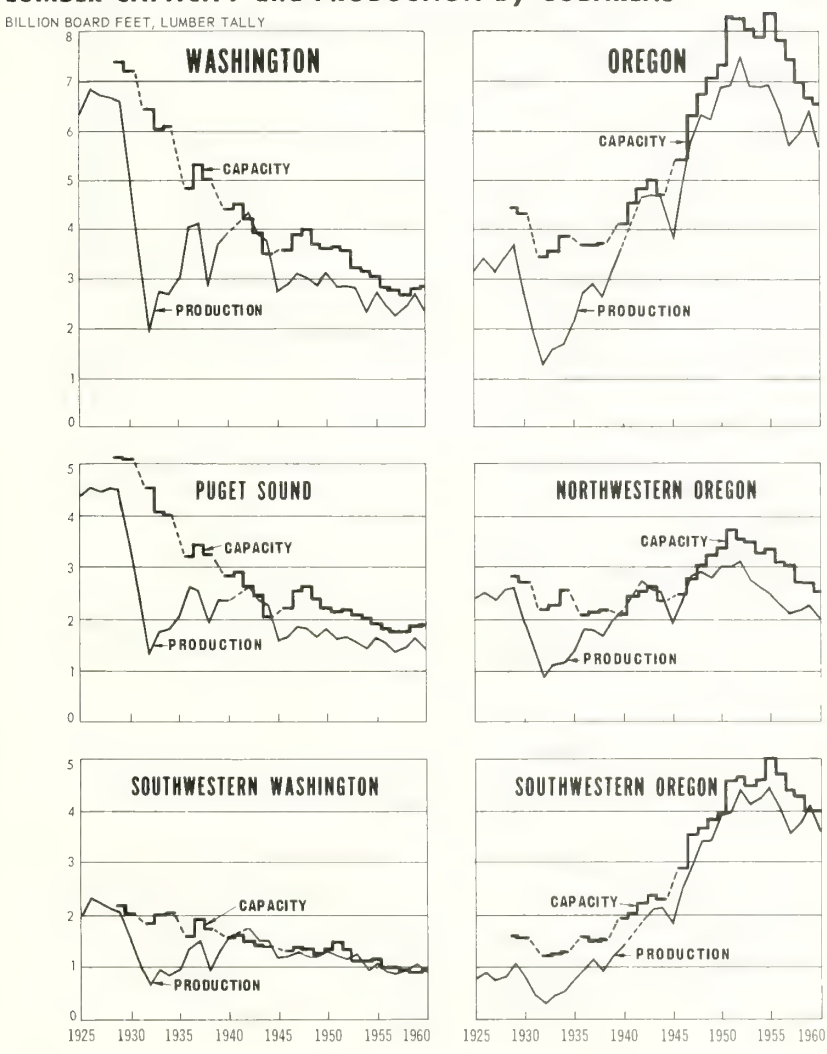


Figure 5. — Annual lumber production and capacity in the Douglas-fir subregion by State and subarea, 1925-60.

Lumber production in western Oregon followed the general pattern of the changes in capacity, but dropped to much lower levels during the 1930's and fell more than a billion feet short of the peak levels of capacity in 1951 and 1955. During the period of most rapid expansion, 1946 to 1950, unused capacity in Oregon averaged only 8 percent, or 554 million board feet. In the following 5 years, when western Oregon's production was at its peak level, unused capacity averaged 1.148 billion board feet, or 14 percent. And in 1960, when capacity had been reduced 1.8 billion feet, unused capacity was still at a high level, 935 million feet, and still 14 percent.

### Unused Sawmill Capacity Has Been Highest In Northwestern Oregon

Expansion of capacity in northwestern Oregon culminated in 1951 at 3.8 billion board feet. Thereafter, it declined 1.2 billion feet to 2.6 billion in 1960 — a substantial reduction of capacity but not as much as the drop in lumber output.

In the 3 years 1950-52, when production was at its historical peak, unused capacity averaged 524 million feet, or 15 percent. In 1959, it was 17 percent and in 1960, 21 percent.

In southwestern Oregon, sawmill capacity continued to expand until 1955 when it reached 5.0 billion board feet. Production culminated in that same year at 4.4 billion feet, with an unused capacity of 570 million feet, or about 10 percent.

After 1955, however, capacity declined even more rapidly than in northwestern Oregon. In 1960, nevertheless, unused capacity was still 10 percent, or 404 million board feet.

## Relationships Among Mill Size Classes

### Largest Mills Show Greatest Decline in Capacity

From 1929 to 1960, the largest mill size class in the Douglas-fir subregion, mills with 120,000 board feet or more per day capacity, declined 8.7 million board feet in daily capacity. As can be seen from figure 6, the daily capacity in this size class in western Washington declined from 18.0 million feet to 5.7 million feet, while in Oregon it increased from 7.9 million feet to 11.5 million feet, offsetting only 30 percent of the decline in western Washington.

All other mill size classes in the Douglas-fir subregion increased total daily capacity between 1929 and 1960. However, the total capacity of the smaller mill size classes, 0 to 39,999 and 40,000 to 79,999 board feet per day, reached a historical peak in 1951, then declined 42 percent and 25 percent, respectively, to their 1960 levels. Mills in the 80,000- to 119,999-feet-

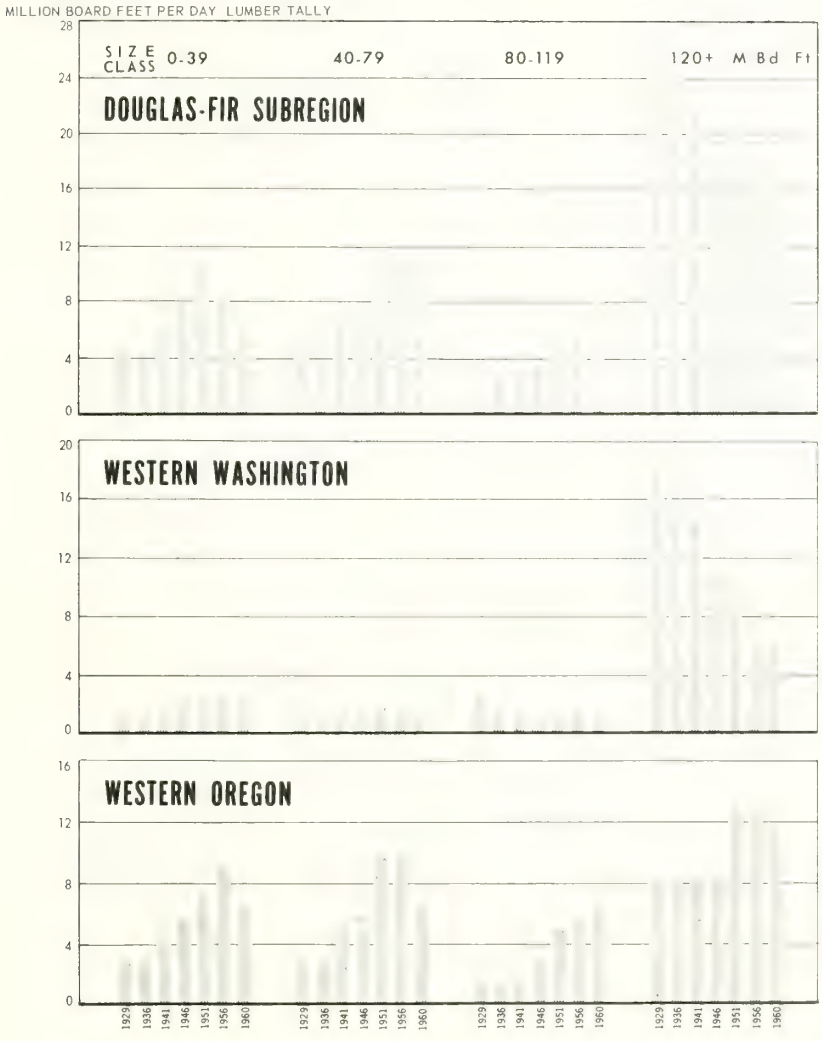


Figure 6. — Daily sawmill capacity by mill size class for Douglas-fir subregion, 1929-60.

per-day class, on the other hand, consistently continued to expand capacity to 1960.

Table 3 presents shifts in share of total annual capacity by mill size class between the early postwar period and the period 1956-58. The biggest change in share of total annual capacity was the decline in relative capacity of the largest size class and the more or less corresponding increase in the 80,000- to 119,999-board-feet-per-day class.

## Mills in 80,000- to 119,999-Board-Feet-Per-Day Class Show Continued Growth in Capacity

In the shift of the center of lumber production from western Washington to western Oregon, western Oregon's sawmill capacity expanded in all mill size classes (fig. 6). The greatest expansion between 1929 and 1951 occurred in the 40,000- to 79,999-board-feet-per-day mill size class. In terms of daily capacity, this expansion was about 6.8 million feet. In the same period, mills with 120,000 feet or more capacity per day increased daily capacity 5.1 million feet. Mills in the 0- to 39,999-feet-per-day class and the 80,000- to 119,999-feet-per-day class increased daily capacity 4.5 and 3.8 million feet, respectively. In terms of number of mills, the greatest expansion, of course, occurred in the smallest size class and next in the 40,000- to 79,999-feet-per-day class.

Table 3. — Percent of annual sawmill capacity by mill size class

| Period | Mill size class in thousands of board feet per day | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Douglas-fir subregion | | | | | Western Washington | | | | | Western Oregon | | | | |
| | All | 0-39 | 40-79 | 80-119 | 120+ | All | 0-39 | 40-79 | 80-119 | 120+ | All | 0-39 | 40-79 | 80-119 | 120+ |
| | Percent | | | | | | | | | | | | | | |
| 1948 to 1952 | 100 | 13 | 20 | 13 | 54 | 100 | 15 | 16 | 13 | 56 | 100 | 10 | 24 | 22 | 44 |
| 1956 to 1958 | 100 | 11 | 21 | 20 | 48 | 100 | 11 | 10 | 10 | 69 | 100 | 15 | 25 | 16 | 44 |

After 1951, however, capacity declined in all size classes except the 80,000- to 119,999-feet-per-day class, with the sharpest declines in the two smallest size classes. Daily capacity in the 80,000- to 119,999-feet-per-day class continued to grow an additional 1.4 million board feet to 1960. Unused capacity in this class, moreover, averaged less than 10 percent of its total annual capacity during this period of continued growth. Mills in the 80,000- to 119,999-feet-per-day class, thus, seem to have been well adapted to economic conditions in the postwar period in the Douglas-fir subregion.

# The Douglas-Fir Plywood Industry

Softwood plywood has been one of the fastest growing nondefense industries in the postwar period. From 1947-60, its output increased 468 percent — from 1,700 million square feet to 7,952 million square feet (3/8-inch basis). Practically all of the capacity of the softwood plywood industry is located in western Washington, western Oregon, and northern California.

## Estimation of Annual Capacity

Annual plywood capacity has been estimated by summing annual capacities reported for individual plants listed in the "Directory of Plywood and Veneer Products" in the annual plywood review issues of The Lumberman, 1957-60, and The Timberman, 1933-56. Estimates of annual capacity are given in table 4. These estimates include the capacity normally not utilized due to seasonal variations in production. Goddard[5] has estimated that 11.5 percent of annual plywood capacity was not utilized in 1951 to 1954 as a result of seasonal variation in production.

# Relationships in the Subregion

## Plywood Capacity Exceeds 9 Billion Square Feet In Pacific Northwest

In 1960, the plywood capacity in the Pacific Northwest[6] was 9,172 million square feet. This was an increase of 422 percent from 1947 when capacity was 2,176 million square feet.

The Douglas-fir plywood industry had its beginnings in Portland, Oreg., in 1905. Its growth in capacity since that time can be divided into five periods, each having a distinctly different growth rate:

| Period | Number of years | Increase in capacity | Average annual increase |
|---|---|---|---|
| | | Million square feet | |
| 1905-33 | 28 | 671 | 24.0 |
| 1933-40 | 7 | 1,096 | 156.7 |
| 1940-47 | 7 | 409 | 58.4 |
| 1947-54 | 7 | 2,154 | 307.7 |
| 1954-60 | 6 | 4,688 | 781.3 |

[5] Goddard, Everett Earl. An analysis of the problem of industrial productivity measurement as applied to the Douglas-fir plywood industry. pp. 247-258. Doctoral thesis on file at University of Washington, Seattle. 1956.

[6] Includes all of Idaho, Montana, Oregon, and Washington since production data cannot be separated for western Oregon and western Washington. Plant capacity in Idaho and Montana, however, was less than 1 percent of the total for the Pacific Northwest from 1952 to 1958, and 1.3 and 2.3 percent in 1959 and 1960, respectively.

Its growth pattern is marked by continuous acceleration to 1960 (fig. 7). From 1958 to 1960, for example, the average annual increase in capacity was 1,069 million square feet, the highest historical rate for any 2-year period.

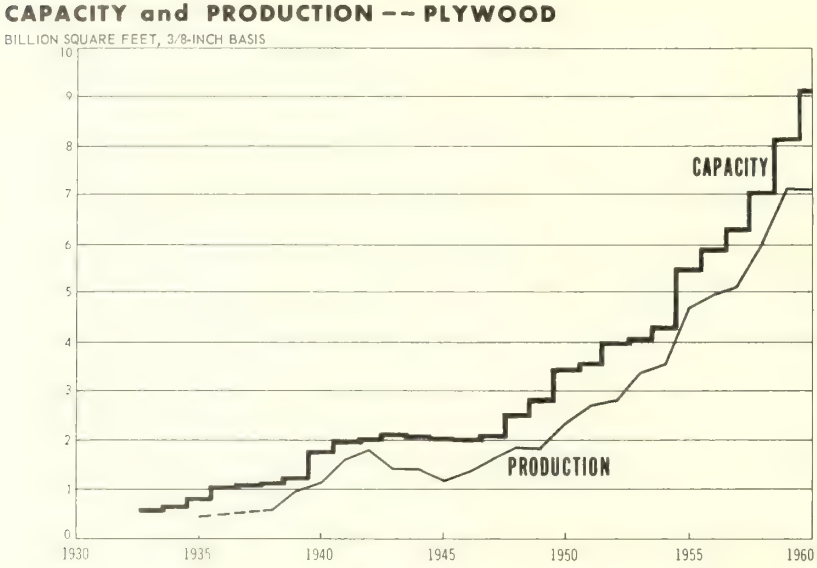


Figure 7.—Annual capacity and production of the plywood industry in the Pacific Northwest, 1933-60.

## Plywood Production Lags Behind Expansion

In 1960, plywood production in the Pacific Northwest was 7,103 million square feet, or 86 percent of the national softwood plywood production.

Except for the war years, 1940-45, growth in plywood capacity led expansion of production by an average of about 3 years. From 1947-59, unused capacity averaged 914 million square feet. Percentagewise, it declined from an average of 29 percent in the first half of this period to 15 percent in the second half.

In 1960, production dropped below that of the previous year for the first time since 1949. Capacity, however, continued to increase by an additional 1,026 million square feet. As a consequence, unused capacity rose to a historical peak of 2,069 million square feet, or 23 percent, as shown in table 4. In this year, it became evident that the industry was confronted

with a serious problem of excess capacity, overproduction, and depressed prices. Unused plywood capacity in Oregon in 1960 was 1,339 million square feet, or 20 percent. In Washington, it was 730 million square feet, or 32 percent.

## Absolute and Relative Plywood Prices Decline

During the early phase of the postwar expansion, 1950-52, the Douglas-fir plywood wholesale price index (1947-49 = 100) averaged 115.1, its highest historical level. By the end of the decade, 1958-60, the index had dropped to 92.3 (fig. 8, upper panel).

The relative price of softwood plywood, i.e., the wholesale price index for Douglas-fir plywood divided by the wholesale price index for all commodities, dropped even more sharply during this period—from 104.9 to 77.2.

Table 4. — Annual capacity and production of the plywood industry in the Pacific Northwest, 1933-60[1]

| Year | Production | Capacity | Unused Capacity | |
|---|---|---|---|---|
| | | | Amount | Percent of capacity |
| | MM sq. ft.[2] | MM sq. ft.[2] | MM sq. ft.[2] | |
| 1933 | -- | 671 | -- | -- |
| 1934 | -- | 721 | -- | -- |
| 1935 | 480 | 876 | 396 | 45 |
| 1936 | -- | 1,086 | -- | -- |
| 1937 | -- | 1,145 | -- | -- |
| 1938 | 650 | 1,163 | 513 | 44 |
| 1939 | 950 | 1,329 | 379 | 29 |
| 1940 | 1,200 | 1,767 | 567 | 32 |
| 1941 | 1,620 | 2,010 | 390 | 19 |
| 1942 | 1,782 | 2,081 | 299 | 14 |
| 1943 | 1,430 | 2,194 | 764 | 35 |
| 1944 | 1,440 | 2,172 | 732 | 34 |
| 1945 | 1,200 | 2,131 | 931 | 44 |
| 1946 | 1,395 | 2,065 | 670 | 32 |
| 1947 | 1,625 | 2,176 | 551 | 25 |
| 1948 | 1,828 | 2,590 | 762 | 29 |
| 1949 | 1,814 | 2,789 | 975 | 35 |
| 1950 | 2,384 | 3,476 | 1,092 | 31 |
| 1951 | 2,702 | 3,579 | 877 | 25 |
| 1952 | 2,838 | 3,994 | 1,156 | 29 |
| 1953 | 3,376 | 4,176 | 800 | 19 |
| 1954 | 3,575 | 4,330 | 755 | 17 |
| 1955 | 4,767 | 5,534 | 767 | 14 |
| 1956 | 4,934 | 5,927 | 993 | 17 |
| 1957 | 5,182 | 6,355 | 1,173 | 18 |
| 1958 | 6,052 | 7,034 | 982 | 14 |
| 1959 | 7,150 | 8,146 | 996 | 12 |
| 1960 | 7,103 | 9,172 | 2,069 | 23 |

[1] Idaho and Montana included for years 1951-60. [2] 3/8-inch basis.

Sources for production: U. S. Bureau of the Census "Facts for Industry" series for the years 1947-60.

Douglas Fir Plywood Association Bul. No. 2800, 1960, for years prior to 1947; includes hardwood plywood production beginning with 72 million square feet in 1951 and amounting to 444 million square feet in 1960.

Sources for capacity: Directories of plywood and veneer products in annual plywood review issues of The Lumberman, 1957-60, and The Timberman, 1933-56.

An industry effort in 1960 to maintain more favorable prices by self-imposed production restrictions revealed the highly competitive character of many producers. Many smaller producers continued to produce at or near capacity. Although a reduction of production among the larger firms kept total annual production from expanding, it was insufficient to keep plywood prices from falling to a new low level.

## Relationships with Lumber Industry

### Plywood Competes with Lumber for Markets

In recent years, the competitive relationships between plywood and lumber changed markedly. Plywood used for sheathing, subflooring, roofing, and other construction purposes has captured a substantial segment of traditional lumber markets.

The increased competition between plywood and lumber is marked by divergent price trends as illustrated in figure 8. During the period 1947-54, the ratio of the wholesale price index for the Douglas-fir subregion averaged 102.6. While the following years, 1955-60, represented the most rapid growth in plywood capacity and production, the ratio fell to 80.9 in 1960.

### Plywood Also Competes with Lumber for Log Supplies

Log requirements of the plywood industry in 1940 were approximately 500 million board feet, about 6 percent of the total log output of the Douglas-fir subregion. In 1950, the industry was using 10 percent of the total log production of the subregion and in 1960, 27 percent, nearly 3 billion board feet per year.

Expanding use of lower grade plywood for construction items has made No. 1 and No. 2 sawmill logs standard raw material for much of the plywood output. Sheathing grades of plywood, which use only C- and D-grade veneers, now comprise close to 30 percent of the plywood output. Only 46 percent[7] of the output in 1957 required an A-grade face; less than 4 percent required two A-grade faces.

With more or less stable level of log production in the subregion during the 1950 decade, it is obvious that the plywood industry increased its log supply from part of the production which formerly had gone into lumber.

[7] Anonymous. State of the industry. The Lumberman 85(1): 67. 1958.

## PLYWOOD and LUMBER PRICE RELATIONSHIPS

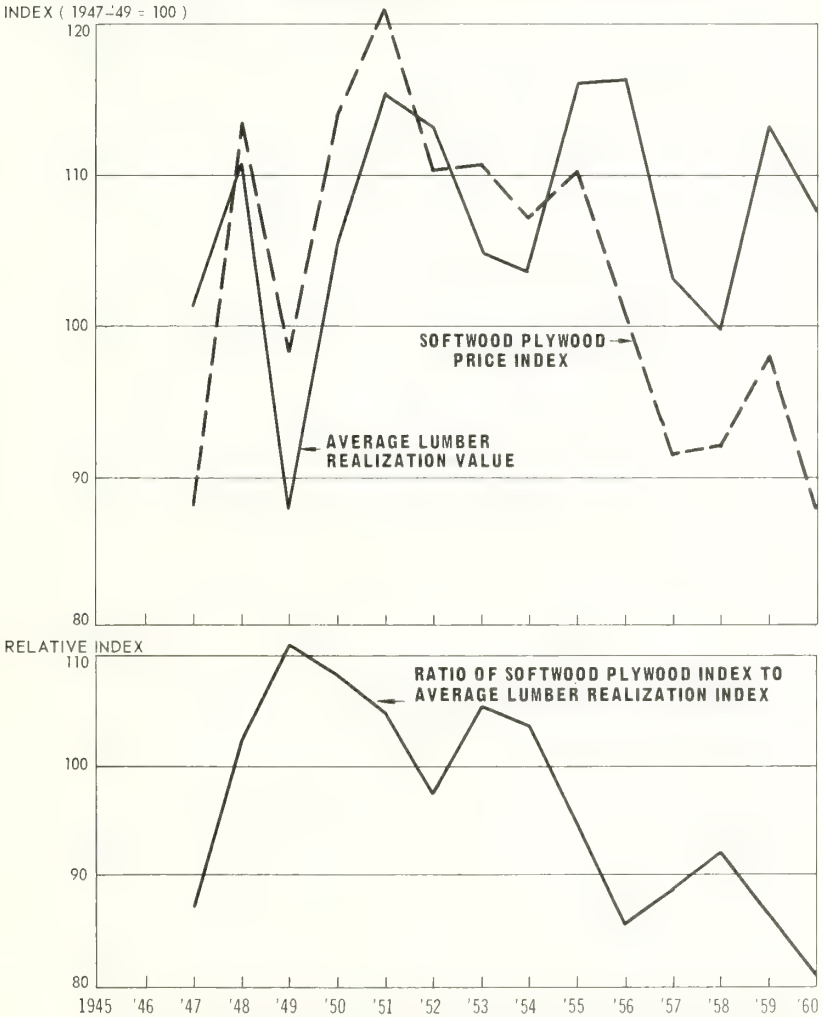


Figure 8.—Price relationships between softwood plywood and lumber from Douglas-fir subregion, 1945-60.

## Plywood Capacity Increase Offsets Lumber Capacity Decrease

The capacity of the lumber industry in the subregion reached a peak in 1951 of 12.0 billion board feet, lumber tally, or 9.6 billion feet, log scale. Plywood capacity in 1951 was 3.6 billion square feet, or 1.5 billion feet, log scale.[8] The combined capacity, measured in terms of common log input units, was 11.1 billion board feet, log scale.

From 1951 to 1960, the combined capacity showed little change, averaging 11.0 billion board feet, log scale, with an average deviation of only 2 percent (table 5, fig. 9). As indicated earlier, this was accompanied by substantial reduction of lumber manufacturing throughout the Douglas-fir subregion.

The combined output of both industries in 1951 amounted to 9.0 billion board feet, log scale, and averaged 9.3 billion feet in the period 1951-60 (table 5, fig. 9).

The unused capacity in the lumber and plywood industries amounted to about 0.8 billion board feet, log scale, in 1959. In 1960, however, it was up to 2.1 billion feet, log scale (table 5), due to continued expansion of plywood capacity and a substantial decline in lumber production.

Table 5. — Annual plywood and lumber capacity and production for the Douglas-fir subregion, 1946-60

| Year | Capacity | | | Production | | | Unused capacity | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lumber | Plywood | Total | Lumber | Plywood[1] | Total | Lumber | Plywood | Total |
| | Million board feet, Scribner log scale | | | | | | | | |
| 1946 | 7,253 | 860 | 8,113 | 6,268 | 581 | 6,849 | 985 | 279 | 1,264 |
| 1947 | 8,295 | 907 | 9,202 | 7,170 | 677 | 7,847 | 1,125 | 230 | 1,355 |
| 1948 | 8,628 | 1,080 | 9,708 | 7,524 | 762 | 8,286 | 1,104 | 318 | 1,422 |
| 1949 | 8,674 | 1,159 | 9,833 | 7,308 | 756 | 8,064 | 1,366 | 403 | 1,769 |
| 1950 | 8,817 | 1,449 | 10,266 | 8,086 | 993 | 9,079 | 731 | 456 | 1,187 |
| 1951 | 9,631 | 1,491 | 11,122 | 7,880 | 1,126 | 9,006 | 1,751 | 365 | 2,116 |
| 1952 | 9,520 | 1,655 | 11,175 | 8,291 | 1,174 | 9,465 | 1,229 | 481 | 1,710 |
| 1953 | 9,043 | 1,724 | 10,767 | 7,796 | 1,395 | 9,191 | 1,247 | 329 | 1,576 |
| 1954 | 8,902 | 1,787 | 10,689 | 7,426 | 1,476 | 8,902 | 1,476 | 311 | 1,787 |
| 1955 | 9,189 | 2,291 | 11,480 | 7,730 | 1,972 | 9,702 | 1,459 | 319 | 1,778 |
| 1956 | 8,550 | 2,451 | 11,001 | 7,007 | 2,041 | 9,048 | 1,543 | 410 | 1,953 |
| 1957 | 8,214 | 2,628 | 10,842 | 6,362 | 2,145 | 8,507 | 1,852 | 483 | 2,335 |
| 1958 | 7,781 | 2,912 | 10,693 | 6,751 | 2,506 | 9,257 | 1,030 | 406 | 1,436 |
| 1959 | 7,627 | 3,349 | 10,976 | 7,283 | 2,941 | 10,224 | 344 | 408 | 752 |
| 1960 | 7,570 | 3,822 | 11,392 | 6,423 | 2,892 | 9,315 | 1,147 | 930 | 2,077 |

[1] Based on plywood production for the Pacific Northwest from table 4 less plywood capacity of Idaho and Montana, after reduction by the percentage of unused capacity reported in table 5 for the Pacific Northwest.

[8] Conversion factors: 125 board feet, lumber tally, per 100 board feet, Scribner log scale; 240 square feet of 3/8-inch plywood per 100 board feet, Scribner log scale. All board-foot log volumes in this report are in Scribner log scale. Conversion factors based on unpublished studies of the Pacific Northwest Forest and Range Experiment Station and the following publications:

Clarke, E. H., and Knauss, A. C. Veneer recovery from Douglas-fir logs. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 23, 13 pp. 1957.

Matson, E. E. Lumber grades from old-growth Douglas-fir sawmill logs. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 125, 2 pp. plus tables and figures. 1956.

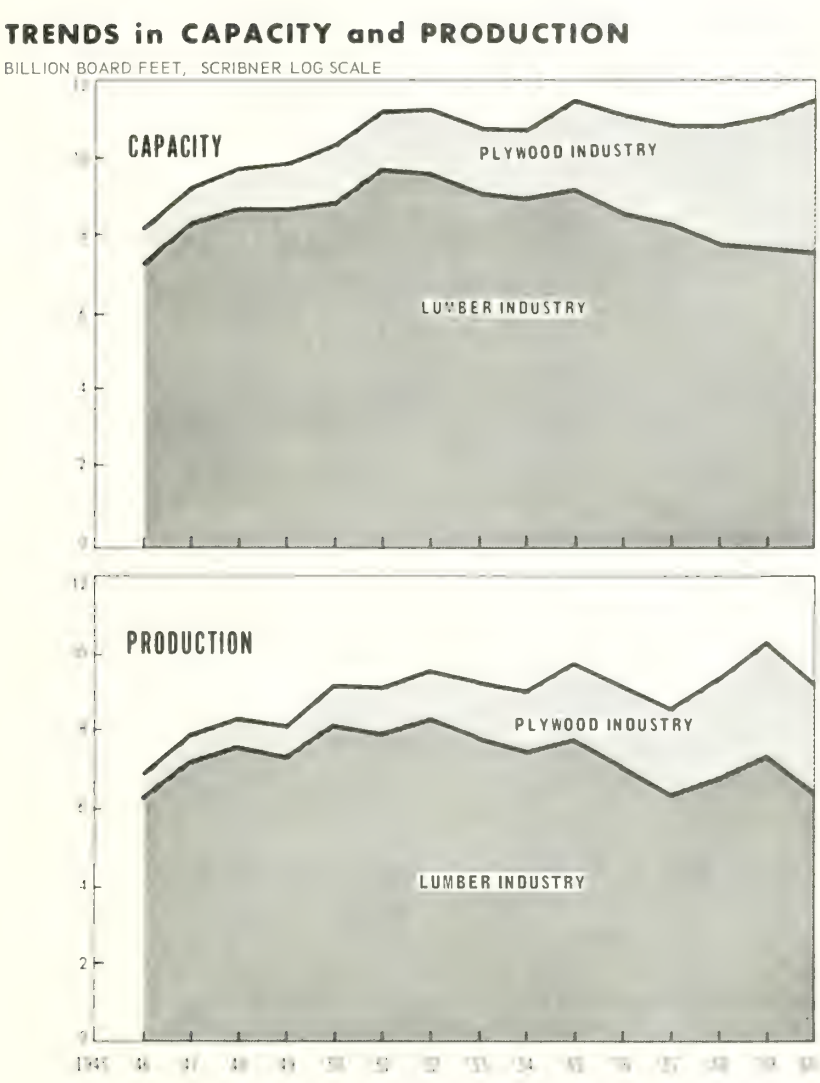


Figure 9.—Trends in plywood and lumber capacity and production in the Douglas-fir subregion, in terms of log consumption, 1946-60.

## Plywood and Lumber Production Integrated More Widely

As plywood capacity expanded in the subregion and plywood-log consumption increased, the degree of integration between the lumber and plywood industries increased, as shown in table 6. In 1960, 43 percent of the plywood capacity was integrated with lumber production. In Oregon, integrated capacity reached 47 percent of total plywood capacity and in Washington, 34 percent.

Table 6. — Degree of integration of plywood and lumber capacity under the same ownership, Douglas-fir subregion, 1937-60

| Item | | 1937 | 1950 | 1955 | 1960 |
|---|---|---|---|---|---|
| Douglas-fir subregion: | | | | | |
| Total plywood capacity | Million sq. ft. | 1,145 | 3,476 | 5,495 | 8,958 |
| Capacity integrated with lumber | Million sq. ft. | 368 | 1,069 | 2,199 | 3,888 |
| Percent integrated | | 32 | 31 | 40 | 43 |
| Oregon: | | | | | |
| Total plywood capacity | Million sq. ft. | 144 | 1,552 | 3,378 | 6,668 |
| Capacity integrated with lumber | Million sq. ft. | 54 | 405 | 1,573 | 3,113 |
| Percent integrated | | 38 | 26 | 47 | 47 |
| Washington: | | | | | |
| Total plywood capacity | Million sq. ft. | 1,001 | 1,924 | 2,117 | 2,290 |
| Capacity integrated with lumber | Million sq. ft. | 314 | 664 | 626 | 775 |
| Percent integrated | | 31 | 35 | 30 | 34 |

Source: Directories of plywood and veneer products in annual plywood review issues of The Lumberman and The Timberman.

The greatest absolute increase in integration of plywood with lumber came between 1955 and 1960 when total plywood capacity was expanding at the highest rate in history. In that period, 1.7 billion square feet, 3/8-inch basis, of plywood capacity was integrated with lumber production. It was during this period also that plywood prices dropped most drastically (fig. 8).

The trend of integration between plywood and lumber has been associated entirely with sawmills having a daily capacity of 80,000 board feet or more. The economy of such integration probably accounts in part for the continued expansion of capacity of sawmills in the 80,000- to 119,999-board-feet-per-day size class and the relatively small attrition in Oregon of sawmills of larger than 120,000-board-feet-per-day capacity.

# Relationships in States and Subareas

## Center of Plywood Industry Shifted to Oregon

The location of the Douglas-fir plywood industry, like the lumber industry, is oriented toward log supply sources but to a lesser degree. In the prewar period, for example, Washington led Oregon in total log pro-

duction, with the Puget Sound area accounting for a third or more of the total log output of the Douglas-fir subregion. Until 1947, two-thirds or more of the subregion's plywood capacity continued to be located in Washington, with 50 percent or more in the Puget Sound area.

After 1941, the center of log production and lumber manufacture shifted to Oregon, with the heaviest concentration in southwestern Oregon. Plywood production shifted similarly, but 10 years later, in 1952, Oregon's plywood output surpassed Washington's for the first time (fig. 10, tables 7 and 8).

From 1947 to 1960, Washington's plywood capacity increased only 870 million square feet, or 60 percent. Oregon's expansion was 5,932 million square feet, or more than 800 percent.

## Plywood Capacity Expands in Western Washington As Lumber Declines

From 1947 to 1960, plywood capacity in western Washington increased 354 million board feet, log scale, while lumber capacity declined 916 million feet, log scale. The combined capacity accordingly declined 562 million feet, from 3.8 billion board feet, log scale, to 3.2 billion feet (fig. 11, table 9).

Log production, on the other hand, remained relatively stable — averaging 3.7 billion board feet after 1947 with an average deviation of 10.8 percent.[9] Economic conditions obviously favored the plywood industry in western Washington in the postwar period. Plywood capacity increased from 16 percent to 29 percent of the combined plywood and lumber capacity.

## One-third of Western Oregon's Lumber and Plywood Capacity in Plywood

The combined capacity of the lumber and plywood industries in western Oregon was 8.1 billion board feet, log scale, in 1960 — an increase of 2.7 billion board feet since 1947. In 1960, plywood constituted 34 percent of the total capacity; in 1947, it was only 6 percent.

The initial increase in total capacity in western Oregon in the postwar period came largely in the lumber industry. Lumber capacity increased from 5.1 billion feet, log scale, in 1947 to 6.7 billion feet in 1951. Plywood increased only 447 million board feet, log scale, in the same period.

[9] A substantial proportion of Washington's log production is used for pulpwood consumption.

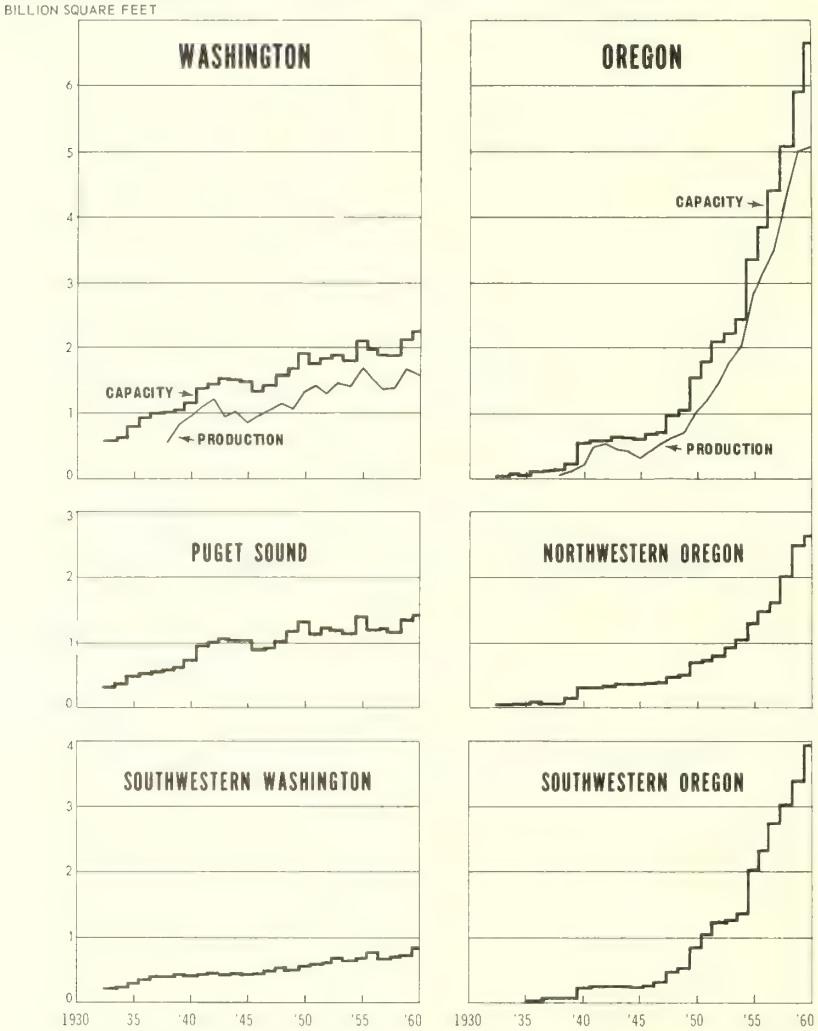


Figure 10.—Annual softwood plywood production and capacity in Washington and Oregon and subareas, 1933-60. (Production data not available separately for subareas. Washington production includes Idaho and Montana output for years 1952-60. Hardwood plywood production not included for either State.)

## Table 7. — Annual plywood capacity by State and subareas, 1933-60

| Year | Washington | | | Oregon | | | Idaho and Montana |
|---|---|---|---|---|---|---|---|
| | Puget Sound | South-western[1] | Total | North-western | South-western[2] | Total | |
| | Million square feet, 3/8-inch basis | | | | | | |
| 1933 | 377 | 240 | 617 | 54 | -- | 54 | -- |
| 1934 | 405 | 252 | 657 | 64 | -- | 64 | -- |
| 1935 | 506 | 300 | 806 | 70 | -- | 70 | -- |
| 1936 | 570 | 380 | 950 | 96 | 40 | 136 | -- |
| 1937 | 596 | 405 | 1,001 | 90 | 54 | 144 | -- |
| 1938 | 605 | 405 | 1,010 | 90 | 63 | 153 | -- |
| 1939 | 648 | 437 | 1,085 | 170 | 74 | 244 | -- |
| 1940 | 757 | 428 | 1,185 | 332 | 250 | 582 | -- |
| 1941 | 967 | 433 | 1,400 | 352 | 258 | 610 | -- |
| 1942 | 1,018 | 453 | 1,471 | 352 | 258 | 610 | -- |
| 1943 | 1,086 | 453 | 1,539 | 397 | 258 | 655 | -- |
| 1944 | 1,063 | 463 | 1,526 | 382 | 264 | 646 | -- |
| 1945 | 1,060 | 433 | 1,493 | 386 | 252 | 638 | -- |
| 1946 | 929 | 436 | 1,365 | 412 | 288 | 700 | -- |
| 1947 | 944 | 496 | 1,440 | 424 | 312 | 736 | -- |
| 1948 | 1,041 | 555 | 1,596 | 496 | 498 | 994 | -- |
| 1949 | 1,199 | 511 | 1,710 | 537 | 542 | 1,079 | -- |
| 1950 | 1,338 | 586 | 1,924 | 705 | 847 | 1,552 | -- |
| 1951 | 1,166 | 603 | 1,769 | 747 | 1,063 | 1,810 | -- |
| 1952 | 1,250 | 619 | 1,869 | 817 | 1,287 | 2,104 | 21 |
| 1953 | 1,209 | 693 | 1,902 | 955 | 1,283 | 2,238 | 36 |
| 1954 | 1,174 | 646 | 1,820 | 1,082 | 1,389 | 2,471 | 39 |
| 1955 | 1,428 | 689 | 2,117 | 1,336 | 2,042 | 3,378 | 39 |
| 1956 | 1,228 | 770 | 1,998 | 1,515 | 2,370 | 3,885 | 44 |
| 1957 | 1,240 | 670 | 1,910 | 1,615 | 2,786 | 4,401 | 44 |
| 1958 | 1,198 | 706 | 1,904 | 2,009 | 3,077 | 5,086 | 44 |
| 1959 | 1,390 | 730 | 2,120 | 2,518 | 3,400 | 5,918 | 108 |
| 1960 | 1,453 | 837 | 2,290 | 2,682 | 3,986 | 6,668 | 214 |

[1] Includes small amount in eastern Washington, 1958-60.
[2] Includes small amount in eastern Oregon, 1952-60.

## Table 8. — Annual plywood production by State, 1938-60

| Year | Softwood plywood | | Hardwood plywood | | |
|---|---|---|---|---|---|
| | Washington[1] | Oregon | Washington[1] | Oregon | Total |
| | Million square feet, 3/8-inch basis | | | | |
| 1938 | 580 | 70 | -- | -- | -- |
| 1939 | 833 | 117 | -- | -- | -- |
| 1940 | 964 | 236 | -- | -- | -- |
| 1941 | 1,123 | 497 | -- | -- | -- |
| 1942 | 1,230 | 552 | -- | -- | - |
| 1943 | 952 | 478 | -- | -- | -- |
| 1944 | 1,012 | 428 | -- | -- | -- |
| 1945 | 878 | 322 | -- | -- | -- |
| 1946 | 963 | 432 | -- | -- | -- |
| 1947 | 1,067 | 558 | -- | -- | -- |
| 1948 | 1,174 | 654 | -- | -- | -- |
| 1949 | 1,091 | 723 | -- | -- | -- |
| 1950 | 1,338 | 1,046 | -- | -- | - |
| 1951 | 1,428 | 1,202 | -- | -- | 72 |
| 1952 | 1,315 | 1,446 | -- | -- | 77 |
| 1953 | 1,478 | 1,803 | -- | -- | 95 |
| 1954 | 1,434 | 2,014 | -- | -- | 127 |
| 1955 | 1,691 | 2,856 | -- | -- | 220 |
| 1956 | 1,527 | 3,180 | -- | -- | 227 |
| 1957 | 1,384 | 3,510 | -- | -- | 288 |
| 1958 | 1,402 | 4,233 | -- | -- | 417 |
| 1959 | 1,673 | 5,003 | -- | -- | 474 |
| 1960 | 1,580 | 5,083 | 194 | 246 | 440 |

[1] Idaho and Montana included for years 1951-60.
Sources for softwood plywood: U. S. Bureau of the Census "Facts for Industry" series, 1947-60; Douglas Fir Plywood Association Bul. No. 2800, 1960, for years prior to 1947.
Sources for hardwood plywood: "State of the Industry," in the annual plywood review issues of The Lumberman, 1957-60, and The Timberman for years before 1957. Sources do not separate hardwood plywood production by States until 1960.

## Table 9. — Annual lumber and plywood capacity in western Washington, 1933-60

| Year | Puget Sound | | | Southwestern Washington | | | Western Washington | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plywood | Lumber | Total | Plywood[1] | Lumber | Total | Plywood[1] | Lumber | Total |
| | Million board feet, Scribner log scale | | | | | | | | |
| 1933 | 157 | 3,256 | 3,413 | 100 | 1,611 | 1,711 | 257 | 4,867 | 5,124 |
| 1934 | 169 | 3,231 | 3,400 | 105 | 1,661 | 1,766 | 274 | 4,892 | 5,166 |
| 1935 | 211 | -- | -- | 125 | -- | -- | 335 | -- | -- |
| 1936 | 238 | 2,591 | 2,829 | 158 | 1,316 | 1,474 | 396 | 3,907 | 4,303 |
| 1937 | 248 | 2,759 | 3,007 | 169 | 1,538 | 1,707 | 417 | 4,297 | 4,714 |
| 1938 | 252 | 2,614 | 2,866 | 169 | 1,422 | 1,591 | 421 | 4,036 | 4,457 |
| 1939 | 270 | -- | -- | 182 | -- | -- | 452 | -- | -- |
| 1940 | 316 | 2,277 | 2,593 | 178 | 1,294 | 1,472 | 494 | 3,571 | 4,065 |
| 1941 | 403 | 2,325 | 2,728 | 180 | 1,321 | 1,501 | 583 | 3,646 | 4,229 |
| 1942 | 424 | 2,144 | 2,568 | 189 | 1,225 | 1,414 | 613 | 3,369 | 3,982 |
| 1943 | 452 | 1,997 | 2,449 | 189 | 1,168 | 1,357 | 641 | 3,165 | 3,806 |
| 1944 | 442 | 1,672 | 2,114 | 193 | 1,150 | 1,343 | 635 | 2,822 | 3,457 |
| 1945 | 442 | -- | -- | 180 | -- | -- | 622 | -- | -- |
| 1946 | 387 | 1,801 | 2,188 | 182 | 1,093 | 1,275 | 569 | 2,894 | 3,463 |
| 1947 | 393 | 2,047 | 2,440 | 207 | 1,142 | 1,349 | 600 | 3,189 | 3,789 |
| 1948 | 434 | 2,103 | 2,537 | 231 | 1,107 | 1,338 | 665 | 3,210 | 3,875 |
| 1949 | 498 | 1,929 | 2,427 | 212 | 1,065 | 1,277 | 710 | 2,994 | 3,704 |
| 1950 | 558 | 1,796 | 2,354 | 244 | 1,111 | 1,355 | 802 | 2,907 | 3,709 |
| 1951 | 486 | 1,737 | 2,223 | 251 | 1,206 | 1,457 | 737 | 2,943 | 3,680 |
| 1952 | 520 | 1,770 | 2,290 | 258 | 1,108 | 1,366 | 778 | 2,878 | 3,656 |
| 1953 | 505 | 1,696 | 2,201 | 288 | 912 | 1,200 | 793 | 2,608 | 3,401 |
| 1954 | 489 | 1,645 | 2,134 | 269 | 920 | 1,189 | 758 | 2,565 | 3,323 |
| 1955 | 596 | 1,545 | 2,141 | 287 | 929 | 1,216 | 883 | 2,474 | 3,357 |
| 1956 | 512 | 1,464 | 1,976 | 320 | 819 | 1,139 | 832 | 2,283 | 3,115 |
| 1957 | 516 | 1,412 | 1,928 | 279 | 826 | 1,105 | 795 | 2,238 | 3,033 |
| 1958 | 499 | 1,411 | 1,910 | 294 | 760 | 1,054 | 793 | 2,171 | 2,964 |
| 1959 | 579 | 1,517 | 2,096 | 304 | 735 | 1,039 | 883 | 2,252 | 3,135 |
| 1960 | 605 | 1,530 | 2,135 | 349 | 764 | 1,113 | 954 | 2,294 | 3,248 |

[1] Includes small amount of plywood capacity in eastern Washington, 1958-60.

After 1951, however, lumber capacity declined 1.4 billion feet, log scale. In 1960, it had almost reached its 1947 level. Plywood, on the other hand, increased capacity 2.0 billion board feet, log scale, more than replacing the reduction in lumber capacity (fig. 11, table 10).

Table 10. — Western Oregon annual lumber and plywood capacity, 1933-60

| Year | Northwestern Oregon | | | Southwestern Oregon | | | Western Oregon | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plywood | Lumber | Total | Plywood[1] | Lumber | Total | Plywood[1] | Lumber | Total |
| | Million board feet, Scribner log scale | | | | | | | | |
| 1933 | 22 | 1,832 | 1,854 | -- | 1,044 | 1,044 | 22 | 2.876 | 2,898 |
| 1934 | 27 | 2,063 | 2,090 | -- | 1,062 | 1,062 | 27 | 3,125 | 3,152 |
| 1935 | 29 | -- | -- | -- | -- | -- | 29 | -- | -- |
| 1936 | 41 | 1,691 | 1,732 | 16 | 1,285 | 1,301 | 57 | 2,976 | 3,033 |
| 1937 | 37 | 1,757 | 1,794 | 22 | 1,234 | 1,256 | 59 | 2,991 | 3,050 |
| 1938 | 37 | 1,773 | 1,810 | 26 | 1,247 | 1,273 | 63 | 3,020 | 3,083 |
| 1939 | 71 | -- | -- | 31 | -- | -- | 102 | -- | -- |
| 1940 | 138 | 1,715 | 1,853 | 104 | 1,590 | 1,694 | 242 | 3,305 | 3,547 |
| 1941 | 147 | 1,985 | 2,132 | 107 | 1,653 | 1,760 | 254 | 3,638 | 3,892 |
| 1942 | 147 | 2,043 | 2,190 | 107 | 1,821 | 1,928 | 254 | 3,864 | 4,118 |
| 1943 | 166 | 2,100 | 2,266 | 107 | 1,920 | 2,027 | 273 | 4,020 | 4,293 |
| 1944 | 159 | 1,915 | 2,074 | 110 | 1,897 | 2,007 | 269 | 3,812 | 4,081 |
| 1945 | 161 | -- | -- | 105 | -- | -- | 266 | -- | -- |
| 1946 | 171 | 2,008 | 2,179 | 120 | 2,351 | 2,471 | 291 | 4,359 | 4,650 |
| 1947 | 177 | 2,239 | 2,416 | 130 | 2,867 | 2,997 | 307 | 5,106 | 5,413 |
| 1948 | 207 | 2,452 | 2,659 | 208 | 2,966 | 3,174 | 415 | 5,418 | 5,833 |
| 1949 | 223 | 2,582 | 2,805 | 226 | 3,098 | 3,324 | 449 | 5,680 | 6,129 |
| 1950 | 294 | 2,715 | 3,009 | 353 | 3,195 | 3,548 | 647 | 5,910 | 6,557 |
| 1951 | 311 | 3,004 | 3,315 | 443 | 3,685 | 4,128 | 754 | 6,689 | 7,443 |
| 1952 | 340 | 2,875 | 3,215 | 537 | 3,767 | 4,304 | 877 | 6,642 | 7,519 |
| 1953 | 398 | 2,833 | 3,231 | 535 | 3,603 | 4,138 | 933 | 6,436 | 7,369 |
| 1954 | 450 | 2,630 | 3,080 | 579 | 3,707 | 4,286 | 1,029 | 6,337 | 7,336 |
| 1955 | 557 | 2,699 | 3,256 | 851 | 4,015 | 4,866 | 1,408 | 6,714 | 8,122 |
| 1956 | 632 | 2,475 | 3,107 | 987 | 3,791 | 4,778 | 1,619 | 6,266 | 7,885 |
| 1957 | 673 | 2,458 | 3,131 | 1,160 | 3,519 | 4,679 | 1,833 | 5,977 | 7,810 |
| 1958 | 837 | 2,170 | 3,007 | 1,282 | 3,440 | 4,722 | 2,119 | 5,610 | 7,729 |
| 1959 | 1,049 | 2,171 | 3,220 | 1,416 | 3,204 | 4,620 | 2,465 | 5,375 | 7,840 |
| 1960 | 1,117 | 2,063 | 3,180 | 1,661 | 3,214 | 4,875 | 2,778 | 5,277 | 8,055 |

[1] Includes small amount of plywood capacity in eastern Oregon, 1952-60.

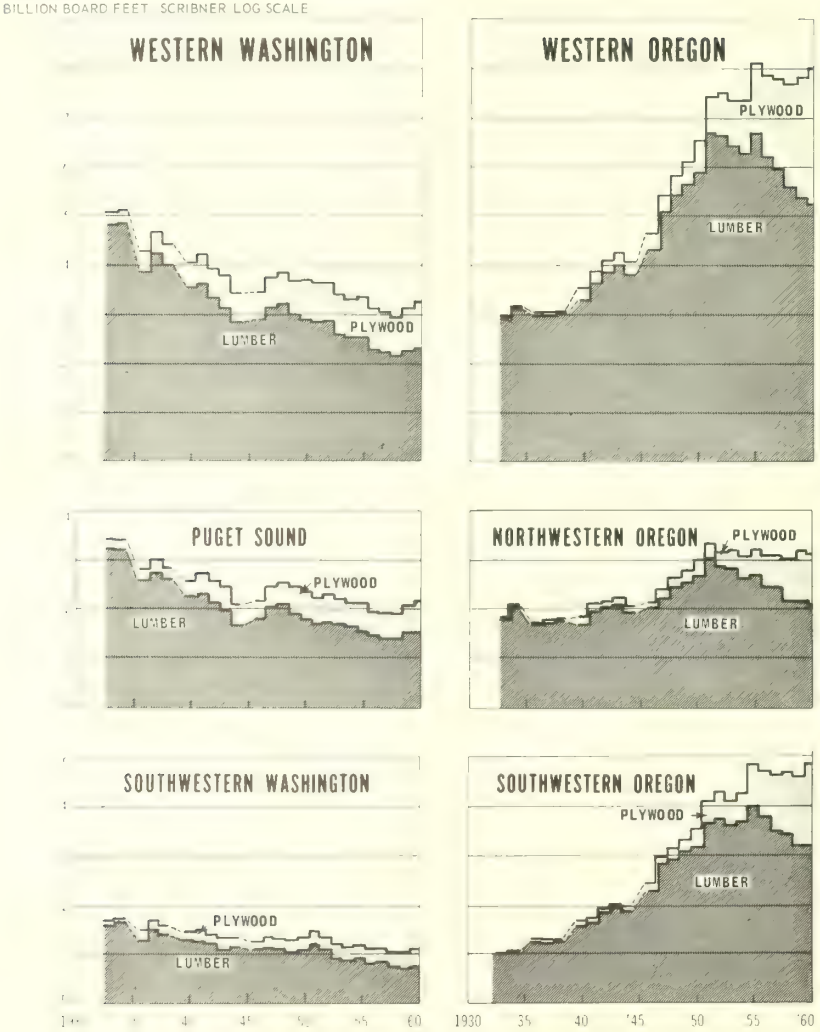


Figure 11.—Annual lumber and plywood capacity for western Washington, western Oregon, and subareas, in terms of log consumption, 1933-60.

# The Pulp Industry

## Estimation of Annual Capacity

Estimates of annual pulp capacity are based upon figures for 24-hour capacity for mills as reported in Lockwood's "Directory of the Paper and Allied Trades." These include hardboard and insulating board mills using a pulping process. Daily capacity was expanded to annual capacity by assuming 350 days of operation. This was the average ratio of reported annual pulp production to reported daily capacity for mills in Washington between 1947 and 1957.

Because pulp production and pulpwood consumption are not reported for portions of a State, this analysis includes eastern Washington and eastern Oregon, where 6 percent of the pulp capacity of these States is located. Alaska's pulp production, which the Bureau of the Census includes with Washington's for years 1955 to 1960, is estimated and excluded.

## Nearly One-sixth of Nation's Pulp Capacity In Pacific Northwest

The annual pulp capacity of Washington and Oregon in 1960 was 4,543,000 tons, constituting approximately 16 percent of the pulp capacity of the United States. Pulp production in 1960 was 3,856,000 tons, giving an unused capacity of 687,000 tons, or 15 percent (fig. 12, tables 11 and 12).

## Pulp Capacity Expands Steadily

Although the pulp industry carried a substantial unused capacity from 1929 to 1940, its capacity expanded consistently in this period at an average rate of 86,000 tons per year. During the war years, expansion slowed considerably (fig. 12). From 1947 to 1960, however, the average annual growth rate rose to 179,000 tons, and pulp capacity in Washington and Oregon increased more than 100 percent.

The postwar expansion in pulp capacity up to 1956 was closely tied to demand, for the installed capacity essentially was fully utilized. Following 1956, however, production failed to stay abreast of the high rate of expansion. Unused capacity rose to 700,000 tons, or 17 percent, and remained at that level through 1960 (table 12).

Table 11. — Annual capacity of pulp industry in Washington, Oregon, and subareas, 1929-60

| Year | Washington | | | | Oregon | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Puget Sound | South-western | Eastern | Subtotal | North-western | South-western | Eastern | Subtotal | |
| | Thousand tons | | | | | | | | |
| 1929 | 373 | 302 | 40 | 715 | 378 | 18 | - | 396 | 1,111 |
| 1930 | -- | -- | -- | -- | -- | -- | -- | -- | - |
| 1931 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1932 | 564 | 362 | 47 | 973 | 433 | 0 | -- | 433 | 1,406 |
| 1933 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1934 | 580 | 362 | 47 | 989 | 435 | 0 | -- | 435 | 1,424 |
| 1935 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1936 | 643 | 396 | 47 | 1,086 | 435 | 24 | -- | 459 | 1,545 |
| 1937 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1938 | 908 | 478 | 47 | 1,433 | 475 | 24 | -- | 499 | 1,932 |
| 1939 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1940 | 961 | 544 | 47 | 1,552 | 476 | 24 | -- | 500 | 2,052 |
| 1941 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1942 | 1,085 | 574 | 47 | 1,706 | 485 | 24 | -- | 509 | 2,215 |
| 1943 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1944 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1945 | 975 | 576 | 47 | 1,598 | 485 | 24 | -- | 509 | 2,107 |
| 1946 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1947 | 1,043 | 600 | 59 | 1,702 | 487 | 24 | -- | 511 | 2,213 |
| 1948 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1949 | 1,108 | 735 | 59 | 1,902 | 557 | 24 | -- | 581 | 2,483 |
| 1950 | 1,118 | 735 | 59 | 1,912 | 536 | 80 | -- | 616 | 2,528 |
| 1951 | 1,153 | 759 | 50 | 1,962 | 550 | 112 | -- | 662 | 2,624 |
| 1952 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1953 | 1,256 | 792 | 50 | 2,098 | 615 | 156 | -- | 771 | 2,869 |
| 1954 | 1,381 | 841 | 50 | 2,272 | 613 | 156 | 91 | 860 | 3,132 |
| 1955 | 1,452 | 1,022 | 50 | 2,524 | 673 | 161 | 91 | 925 | 3,449 |
| 1956 | 1,497 | 1,128 | 50 | 2,675 | 720 | 161 | 91 | 972 | 3,647 |
| 1957 | 1,514 | 1,195 | 50 | 2,759 | 750 | 178 | 91 | 1,019 | 3,778 |
| 1958 | 1,548 | 1,260 | 50 | 2,858 | 886 | 189 | 161 | 1,236 | 4,094 |
| 1959 | 1,548 | 1,384 | 102 | 3,034 | 935 | 189 | 161 | 1,285 | 4,319 |
| 1960 | 1,584 | 1,449 | 120 | 3,153 | 1,040 | 189 | 161 | 1,390 | 4,543 |

## Table 12. — Annual pulp production and unused pulp capacity in Washington and Oregon, 1925-60

| Year | Production | | | Unused Capacity[1] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Washington | Oregon | Total | Washington | Oregon | Total | Washington | Oregon | Total |
| | M tons | | | M tons | | | Percent | | |
| 1925 | 162 | 161 | 323 | -- | -- | -- | -- | -- | -- |
| 1926 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1927 | 268 | 201 | 469 | -- | -- | -- | -- | -- | -- |
| 1928 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1929 | 524 | [2]256 | 780 | 190 | 139 | 329 | 27 | 35 | 30 |
| 1930 | 566 | [2]249 | 815 | -- | -- | -- | -- | -- | -- |
| 1931 | 580 | 238 | 818 | -- | -- | -- | -- | -- | -- |
| 1932 | 421 | 187 | 608 | 552 | 246 | 798 | 57 | 57 | 57 |
| 1933 | 584 | 189 | 773 | -- | -- | -- | -- | -- | -- |
| 1934 | 709 | 240 | 949 | 280 | 195 | 475 | 28 | 45 | 33 |
| 1935 | 776 | 262 | 1,038 | -- | -- | -- | -- | -- | -- |
| 1936 | 896 | 303 | 1,199 | 189 | 156 | 345 | 17 | 34 | 22 |
| 1937 | 1,184 | 339 | 1,523 | -- | -- | -- | -- | -- | -- |
| 1938 | 837 | 251 | 1,088 | 596 | 248 | 844 | 42 | 50 | 44 |
| 1939 | 1,126 | 288 | 1,414 | -- | -- | -- | -- | -- | -- |
| 1940 | 1,443 | 396 | 1,839 | 109 | 104 | 213 | 7 | 21 | 10 |
| 1941 | 1,610 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1942 | 1,573 | -- | -- | 133 | -- | -- | 8 | -- | -- |
| 1943 | 1,153 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1944 | 1,256 | -- | -- | -- | -- | -- | -- | -- | -- |
| 1945 | 1,265 | 361 | 1,626 | 332 | 149 | 481 | 21 | 29 | 23 |
| 1946 | 1,333 | 407 | 1,740 | -- | -- | -- | -- | -- | -- |
| 1947 | 1,591 | 436 | 2,027 | 111 | 75 | 186 | 7 | 15 | 8 |
| 1948 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1949 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1950 | 1,871 | 527 | 2,398 | 41 | 89 | 130 | 2 | 14 | 5 |
| 1951 | 2,065 | 625 | 2,690 | (103) | 37 | (66) | (5) | 6 | (3) |
| 1952 | 2,068 | 616 | 2,684 | -- | -- | -- | -- | -- | -- |
| 1953 | 2,158 | 650 | 2,808 | (60) | 121 | 61 | (3) | 16 | 2 |
| 1954 | 2,383 | 682 | 3,065 | (112) | 178 | 66 | (5) | 21 | 2 |
| 1955 | 2,572 | 834 | 3,406 | (47) | 90 | 43 | (2) | 10 | 1 |
| 1956 | 2,674 | 930 | 3,604 | 0 | 42 | 42 | 0 | 4 | 1 |
| 1957 | 2,641 | 897 | 3,538 | 117 | 122 | 239 | 4 | 12 | 6 |
| 1958 | 2,448 | 970 | 3,418 | 445 | 266 | 711 | 15 | 22 | 17 |
| 1959 | 2,555 | 1,023 | 3,578 | 515 | 262 | 777 | 17 | 20 | 18 |
| 1960 | 2,822 | 1,034 | 3,856 | 331 | 356 | 687 | 10 | 26 | 15 |

[1] Parentheses indicate excess of production over estimated capacity
[2] Includes small amount from California.
Source for production: U. S. Bureau of the Census reports.

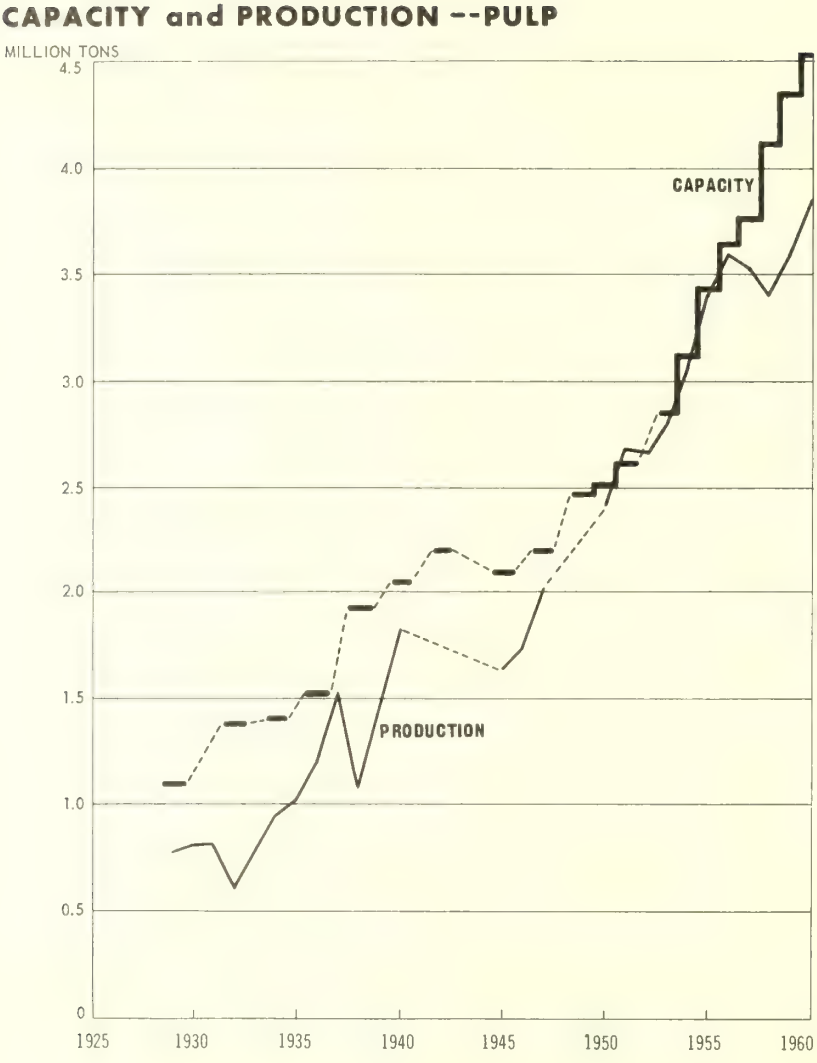


Figure 12.—Annual pulp capacity and production in Washington and Oregon, 1929-60.

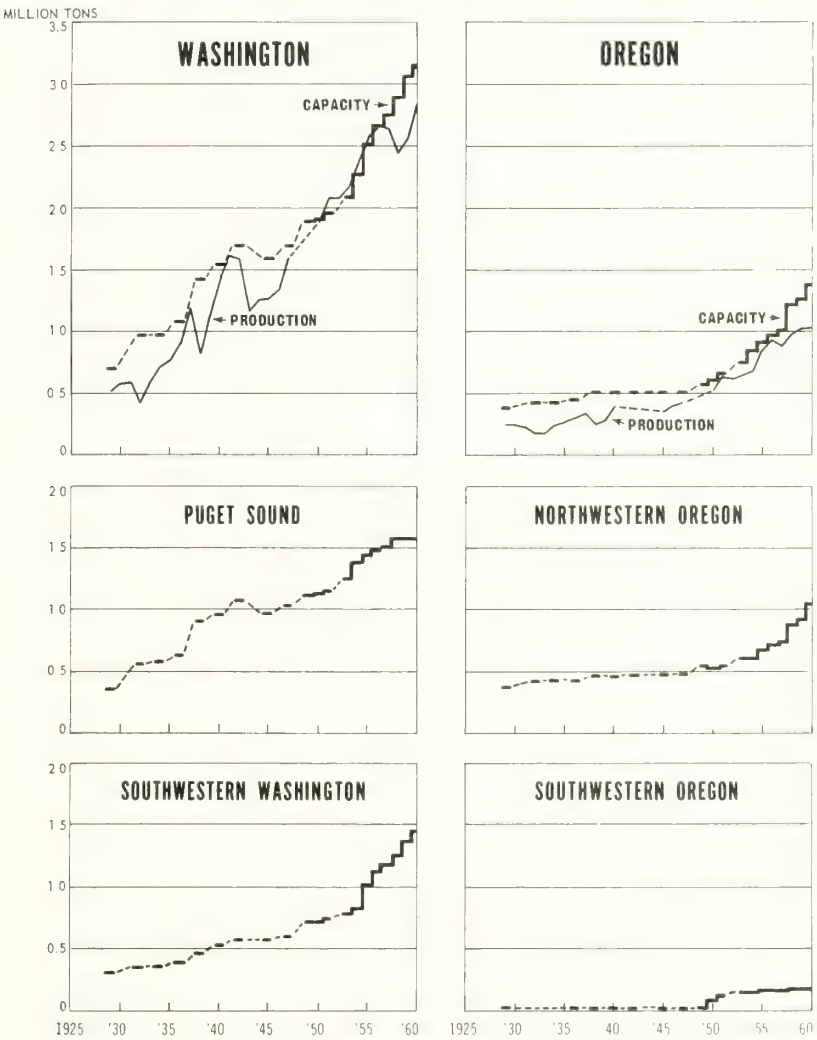


Figure 13.—Annual pulp capacity and production by State and subareas, 1930-60. (State totals include small amounts in eastern Washington and eastern Oregon.)

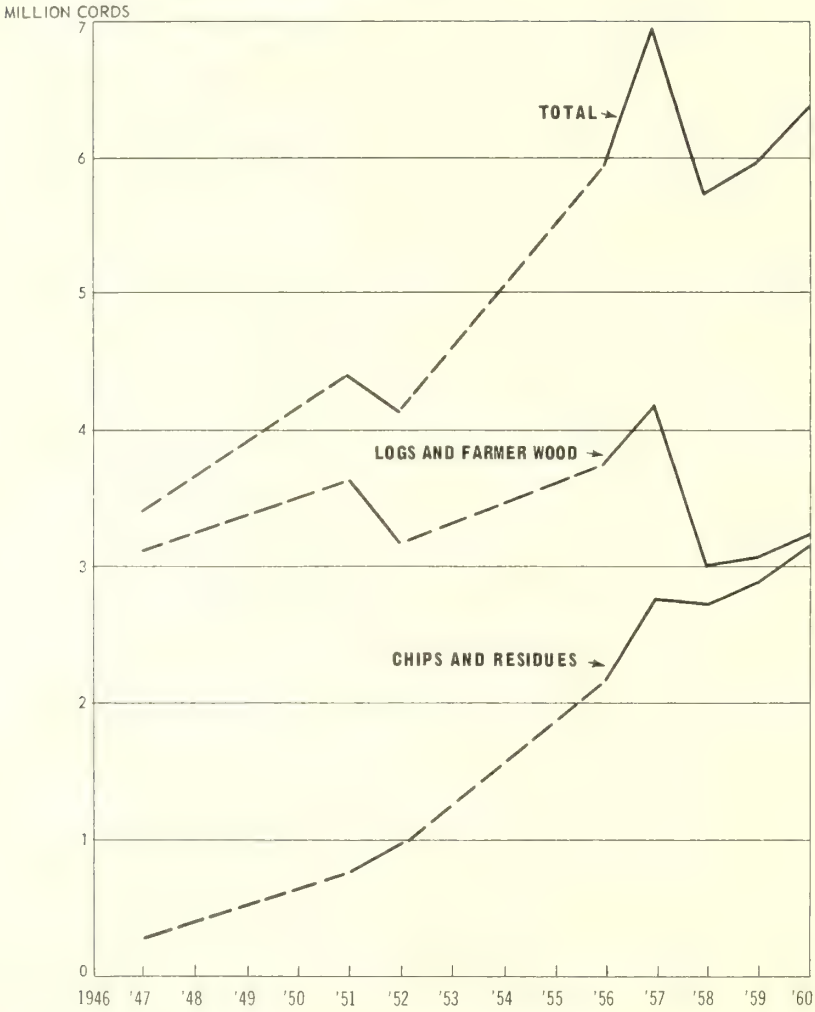


Figure 14.—Pulpwood consumption in Washington and Oregon, 1947-60.

## Center of Pulp Capacity Shifting Southward From Puget Sound

From 1938 to 1951, 74 percent of the pulp capacity of Washington and Oregon was consistently located in western Washington with the heaviest concentration, 46 percent of the total, in the Puget Sound subarea.

Since 1951, the center of concentration of pulp capacity has shifted southward (fig. 13, table 11). In 1960, western Washington's pulp capacity had declined to 67 percent of the total. Western Oregon's share increased correspondingly from 24 percent in the 1940's to 27 percent in 1960. In

Table 13. — Pulpwood consumption in Washington and Oregon, 1929-60

| Year | Washington | | | Oregon | | | Oregon and Washington | | |
|---|---|---|---|---|---|---|---|---|---|
| | Logs and farmer wood | Chips and residue | Total | Logs and farmer wood | Chips and residue | Total | Logs and farmer wood | Chips and residue | Total |
| | Thousand cords | | | | | | | | |
| 1929[1] | -- | -- | -- | -- | -- | -- | 750 | 500 | 1,250 |
| 1930[2] | 568 | -- | -- | 395 | -- | -- | 963 | -- | -- |
| 1931 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1932 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1933 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1934 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1935 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1936[1] | -- | -- | -- | -- | -- | -- | 1,780 | 220 | 2,000 |
| 1937 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1938 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1939 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1940 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1941 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1942 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1943 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1944[3] | 2,329 | -- | -- | 1,189 | -- | -- | 3,518 | -- | -- |
| 1945 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1946 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1947[4] | 2,592 | 254 | 2,846 | 530 | 36 | 566 | 3,122 | 290 | 3,412 |
| 1948 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1949 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1950 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1951[4] | 2,892 | 705 | 3,597 | 733 | 76 | 809 | 3,625 | 781 | 4,406 |
| 1952[5] | 2,215 | 594 | 2,809 | 959 | 375 | 1,334 | 3,174 | 969 | 4,143 |
| 1953 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1954 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1955 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 1956[4] | 3,011 | 1,736 | 4,747 | 745 | 429 | 1,174 | 3,756 | 2,165 | 5,921 |
| 1957[4] | 3,563 | 2,177 | 5,740 | 634 | 568 | 1,202 | 4,197 | 2,745 | 6,942 |
| 1958[4] | 2,465 | 1,932 | 4,397 | 554 | 785 | 1,339 | 3,019 | 2,717 | 5,736 |
| 1959[4] | 2,496 | 2,031 | 4,527 | 576 | 846 | 1,422 | 3,072 | 2,877 | 5,949 |
| 1960[4] | 2,616 | 2,205 | 4,821 | 616 | 928 | 1,544 | 3,232 | 3,133 | 6,365 |

[1] Figures for 1929 and 1936 are for pulpwood consumption. Source: Andrews, H. J., and Cowlin, R. W. Forest resources of the Douglas-fir region. U. S. Dept. Agr. Misc. Pub. 389, 169 pp., illus. 1940.

[2] Figures for 1930 are for production of forest pulpwood. Source: Same as footnote 1.

[3] Figures are for timber cut from commercial forests for pulpwood in 1944. Source: Unpublished data on file Pacific Northwest Forest & Range Experiment Station.

[4] Source for 1947, 1951, 1956, 1957, 1958, 1959, and 1960: Economic survey. Northwest Pulp & Paper Association, Tacoma, Wash.

[5] Source for 1952: Gedney, D. R. Annual cut and timber products output in the Pacific Northwest in 1952. U. S. Forest Serv. Pac. NW. Forest & Range Exp. Sta. Forest Survey Rpt. 126, 29 pp., illus. 1956. Based on conversion of 85 cubic feet per cord.

the same period, pulp capacity in eastern Washington and eastern Oregon increased from 2 percent to 6 percent of the total, with the greater increase in eastern Oregon.

## Postwar Expansion of Pulp Capacity Based on Chips

Almost all of the expansion in pulpwood consumption in Washington and Oregon after 1947 was based on chips and residues from the lumber and plywood industries. Prior to 1947, residues provided about 10 percent of the total pulpwood requirements. By 1957, however, residue used for pulp totaled 2.7 million cords, or 40 percent of the pulpwood consumed, and in 1960, 49 percent (fig. 14, table 13).

Roundwood consumption increased from 3.1 million cords in 1947 to 4.2 million cords in 1957. Since 1957, roundwood consumption has averaged about 3.1 million cords, or 51 percent of the total consumption of 6.0 million cords.

In Oregon, 60 percent of the pulpwood consumption in 1960 was in the form of chips and residues; in Washington, the percentage was 46 percent (table 14).

Table 14. — Proportion of chips and mill residues in total pulpwood consumption, 1929-60

| Year | Washington | Oregon | Total |
|---|---|---|---|
| | Percent | | |
| 1929 | -- | -- | 40 |
| 1936 | -- | -- | 11 |
| 1947 | 9 | 6 | 8 |
| 1951 | 20 | 9 | 18 |
| 1952 | 21 | 28 | 23 |
| 1956 | 39 | 37 | 37 |
| 1957 | 38 | 47 | 40 |
| 1958 | 44 | 59 | 47 |
| 1959 | 45 | 59 | 48 |
| 1960 | 46 | 60 | 49 |

## Sulfate Process Now Exceeds Sulfite Capacity

From 1936 to 1947, the sulfite process constituted about 54 percent of the pulp capacity in Washington and Oregon. The groundwood process constituted 23 percent and sulfate, 20 percent.

In the expansion from 1947 to 1960, sulfate capacity increased 1.3 million tons, making up 57 percent of the expansion. Sulfite increased 0.6 million tons and other processes, 0.4 million tons. In 1960, sulfate made up 40 percent of the annual capacity; sulfite, 38 percent.

Table 15 shows the distribution of capacity by process in Washington and Oregon. The sulfite process still dominates the pulp industry in Washington, where it constitutes 46 percent of the pulp capacity. In Oregon, the sulfate process constitutes 41 percent of the total capacity, with the balance divided more or less equally among other major process categories.

Table 15. — Distribution of annual pulp capacity by process in Washington and Oregon, 1960

| Area | Pulp Process | | | |
|---|---|---|---|---|
| | Sulfite | Sulfate | Groundwood | Other |
| | Thousand tons | | | |
| Puget Sound | 880 | 429 | 258 | 17 |
| Southwestern Washington | 560 | 735 | 66 | 88 |
| Eastern Washington | 15 | 70 | 35 | -- |
| Total Washington | 1,455 | 1,234 | 359 | 105 |
| Northwestern Oregon | 245 | 429 | 250 | 116 |
| Southwestern Oregon | 32 | 140 | -- | 17 |
| Eastern Oregon | -- | -- | -- | 161 |
| Total Oregon | 277 | 569 | 250 | 294 |
| Total | 1,732 | 1,803 | 609 | 399 |

## Hemlock Roundwood and Douglas-fir Chips Principal Pulpwood Sources

Only limited data are readily available on the species composition of pulpwood consumption. However, in 1956, hemlock was the principal species of roundwood used in Washington, constituting 44.4 percent of total consumption of all pulpwood in that year (table 16). Douglas-fir chips and residues were next in importance, accounting for 21.8 percent of the total.

Table 16. — Species composition of pulpwood consumption in Washington, 1956

| Species | Chips and mill residues | Logs and farmer wood | Total |
|---|---|---|---|
| | Percent | | |
| Hemlock | 8.3 | 44.4 | 52.7 |
| Douglas-fir | 21.8 | 6.8 | 28.6 |
| True fir | 1.5 | 6.1 | 7.6 |
| Alder | (1) | 3.1 | 3.1 |
| Cottonwood | .1 | 2.3 | 2.4 |
| Spruce | .2 | 1.9 | 2.1 |
| Cedar | 1.5 | (1) | 1.5 |
| Other species | .5 | 1.5 | 2.0 |
| Total | 33.9 | 66.1 | 100.0 |

[1] Less than 0.1 percent.
Source: Erickson, Dr. Harvey D. Wood supply and production of the pulp industry in the State of Washington. Wash. State Inst. Forest Prod. New Wood Use Ser. Cir. 32, 39 pp., illus. 1957.

For the Pacific Northwest as a whole, it is estimated that hemlock roundwood constitutes about 35 percent of total pulpwood consumption and Douglas-fir chips and residues, about 30 percent.

## Pulpwood Requirements Only 16 Percent Of Total Log Production

Total log consumption for pulpwood has remained relatively stable in the postwar period, averaging about 1.7 billion board feet, log scale,[10] per year, or 16 percent of the total log output of the Douglas-fir subregion.

In western Oregon, log consumption for pulpwood has averaged about 5 percent of total log output. In western Washington, log consumption for pulpwood has varied between 30 and 40 percent of total log output with most of the demand being for hemlock.

In the case of hemlock and true fir pulp logs, there has been some competition between the pulp industry and the lumber and plywood industries for logs but little competition for Douglas-fir logs and other species. Both sawmills and veneer mills have increased their use of hemlock logs since World War II. In western Washington, for example, hemlock lumber output nearly doubled between 1945 and 1960, increasing from 17 percent to 38 percent of the total lumber produced.

Except for the competition for hemlock logs, the pulp industry has had a favorable influence on both the lumber and the plywood industry through its program for utilizing chips from mill residues. In many instances, the pulp industry has provided the initiative and financial arrangements for installing chipping facilities at sawmills. The market for pulp chips has tended to favor the larger mills having a daily capacity of 80,000 board feet or more. As log prices have risen in the postwar period, moreover, the pulp industry has tended to divert its better grade logs to lumber and plywood use, particularly hemlock, and substitute lower grade logs in fulfilling its annual log requirements.

## Unused Pulping Capacity About 450 Million Board Feet, Log Scale, in 1960

In 1960, pulp capacity in terms of pulpwood input was 7.3 million cords, based on consumption of 1.6 cords of pulpwood per ton of pulp production. Actual consumption was 6.4 million cords. Unused capacity, accordingly, was 0.9 million cords or 450 million board feet, log scale.

[10] Based on consumption of 1.6 cords of pulpwood per ton of pulp production.

# Total Log Production in the Subregion

## Annual Log Production at Highest Level in Subregion, 1948-60

In the Douglas-fir subregion, annual log production[11] reached a historical peak of 12.2 billion board feet in 1952, about 13 percent above the average of 10.9 billion board feet in the period 1947-60 as shown in table 17.

Table 17. — Average annual log production in the Douglas-fir subregion for periods since 1904

| Period | Production |
|---|---|
| | Million board feet, Scribner log scale |
| 1904-09 | 4,262 |
| 1910-19 | 5,431 |
| 1920-29 | 8,356 |
| 1930-35 | 5,038 |
| 1936-46 | 8,297 |
| 1947-60 | 10,862 |

After 1952, log production declined more or less steadily to 10.8 billion board feet in 1960, the average level for the postwar period (fig. 15, table 18).

## Center of Log Production Shifts to Southwestern Oregon

Western Oregon's log production expanded from an average annual output of 2.3 billion board feet in the 1930's to 8.7 billion feet in 1952. It exceeded western Washington's output for the first time in 1941 when its production reached 5.3 billion feet. Log production was centered in northwestern Oregon until 1945 and thereafter in southwestern Oregon (fig. 16, table 18).

[11] Includes volume removed as logs but not volume removed for poles, piling, and woodcutting operations. Includes volume from live and dead trees.

Figure 15.—Annual log production in the Douglas-fir subregion, 1925-60.

After 1952, Oregon's log output declined steadily to 6.9 billion board feet in 1960 (fig. 15), and was about equally divided between northwestern and southwestern Oregon (fig. 16, table 18). This downward trend accounted for most of the subregion's decline in log production since the early 1950's, for western Washington's log output showed no trend in the postwar period. It averaged 3.7 billion feet from 1948 to 1960 with an average deviation of 8 percent or 306 million board feet. The pattern was about the same in the Puget Sound and southeastern Washington subareas.

## Private Log Production Declines 2.5 Billion Feet After 1952

In the postwar period, log production from private lands in the Douglas-fir subregion increased rapidly to 9.4 billion board feet in 1952 (fig. 17, table 19). Thereafter, it declined more or less consistently to 6.9 billion feet in 1960. Practically all the decline after 1952 was in western Oregon where it amounted to 2.4 billion board feet. In western Washington the change between 1952 and 1960 was less than 100 million board feet.

Table 18.—Log production in the Douglas-fir subregion by subareas, 1925-60

| Year | Washington | | | Oregon | | | Douglas-fir subregion |
|---|---|---|---|---|---|---|---|
| | Puget Sound | South-western | State | North-western | South-western | State | |
| | Million board feet, Scribner log scale | | | | | | |
| 1925 | 3,622 | 2,344 | 5,966 | 2,159 | 716 | 2,875 | 8,841 |
| 1926 | 3,373 | 2,548 | 5,921 | 2,147 | 761 | 2,908 | 8,829 |
| 1927 | 3,743 | 2,631 | 6,374 | 2,205 | 794 | 2,999 | 9,373 |
| 1928 | 4,145 | 2,532 | 6,677 | 2,307 | 793 | 3,100 | 9,777 |
| 1929 | 4,051 | 2,778 | 6,829 | 2,427 | 1,038 | 3,465 | 10,294 |
| 1930 | 2,585 | 1,755 | 4,340 | 1,616 | 592 | 2,208 | 6,548 |
| 1931 | 1,918 | 1,313 | 3,231 | 1,197 | 384 | 1,581 | 4,812 |
| 1932 | 1,077 | 965 | 2,042 | 803 | 267 | 1,070 | 3,112 |
| 1933 | 1,779 | 1,415 | 3,194 | 1,146 | 429 | 1,575 | 4,769 |
| 1934 | 1,989 | 1,387 | 3,376 | 1,261 | 744 | 2,005 | 5,381 |
| 1935 | 2,148 | 1,204 | 3,352 | 1,517 | 738 | 2,255 | 5,607 |
| 1936 | 2,953 | 1,667 | 4,620 | 1,901 | 962 | 2,863 | 7,483 |
| 1937 | 3,059 | 1,602 | 4,661 | 2,051 | 1,324 | 3,375 | 8,036 |
| 1938 | 2,049 | 988 | 3,037 | 1,787 | 965 | 2,752 | 5,789 |
| 1939 | 2,771 | 1,254 | 4,025 | 2,046 | 1,303 | 3,349 | 7,374 |
| 1940 | 3,177 | 1,343 | 4,520 | 2,418 | 1,462 | 3,880 | 8,400 |
| 1941 | 3,298 | 1,351 | 4,649 | 3,188 | 2,078 | 5,266 | 9,915 |
| 1942 | 3,231 | 1,188 | 4,419 | 3,134 | 2,103 | 5,237 | 9,656 |
| 1943 | 2,854 | 1,301 | 4,155 | 3,134 | 2,421 | 5,555 | 9,710 |
| 1944 | -- | -- | -- | -- | -- | -- | -- |
| 1945 | 2,012 | 967 | 2,979 | 2,488 | 2,345 | 4,833 | 7,812 |
| 1946 | 2,117 | 1,246 | 3,363 | 2,674 | 2,760 | 5,434 | 8,797 |
| 1947 | -- | -- | -- | 3,345 | 3,289 | 6,634 | -- |
| 1948 | 2,184 | 1,330 | 3,514 | 3,328 | 3,876 | 7,204 | 10,718 |
| 1949 | 2,095 | 1,213 | 3,308 | 2,832 | 3,121 | 5,953 | 9,261 |
| 1950 | 2,471 | 1,482 | 3,953 | 2,863 | 3,943 | 6,806 | 10,759 |
| 1951 | 2,572 | 1,555 | 4,127 | 2,801 | 4,612 | 7,413 | 11,540 |
| 1952 | 2,363 | 1,220 | 3,583 | 3,235 | 5,430 | 8,665 | 12,248 |
| 1953 | 2,251 | 1,439 | 3,690 | 2,806 | 4,537 | 7,343 | 11,033 |
| 1954 | 2,067 | 1,248 | 3,315 | 2,630 | 4,808 | 7,438 | 10,753 |
| 1955 | 2,351 | 1,541 | 3,892 | 2,895 | 5,308 | 8,203 | 12,095 |
| 1956 | 2,474 | 1,794 | 4,268 | 3,073 | 4,640 | 7,713 | 11,981 |
| 1957 | 1,978 | 1,319 | 3,297 | 2,366 | 3,831 | 6,197 | 9,494 |
| 1958 | 1,809 | 1,299 | 3,108 | 2,182 | 4,028 | 6,210 | 9,318 |
| 1959 | 2,453 | 1,513 | 3,966 | 2,559 | 4,660 | 7,219 | 11,185 |
| 1960 | 2,332 | 1,557 | 3,889 | 2,322 | 4,607 | 6,929 | 10,818 |

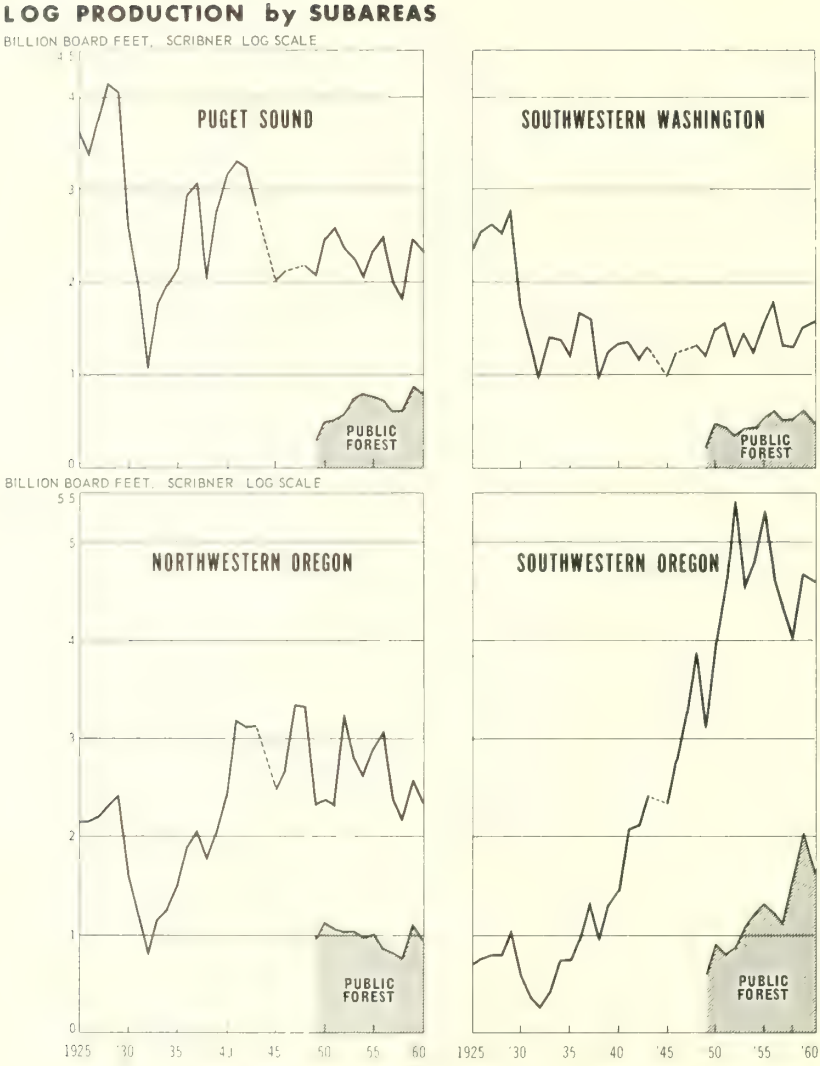


Figure 16.—Annual log production for subareas of the Douglas-fir subregion, 1925-60. Production from public forests shown in shaded segment for 1949-60.

## Log Production From Public Lands Expands 1 Billion Feet After 1952

The annual log harvest from public lands in the subregion reached a level of 1 billion board feet about 1940. By 1949, it had doubled to 2 billion board feet, constituting somewhat more than 20 percent of the total log output in the subregion. About a third of this public harvest in the late 1940's, however, was salvage from State and county lands in the Tillamook Burn.

In 1952, when private log production peaked at 9.4 billion feet, the log harvest from public lands was 2.8 billion board feet, 23.2 percent of the total cut. In 1959, the harvest of public timber reached a peak of 4.6 billion feet, or more than 41 percent of the total cut.

## Increase in Harvest From Public Lands Greatest in Southwestern Oregon

In western Washington, log production from public lands increased uniformly in the postwar period and tended to offset more or less completely the decline in log output from private lands between 1950 and 1960 (fig. 17, table 19). Table 20 brings out the increasing relative importance of the public harvest between 1950 and 1960.

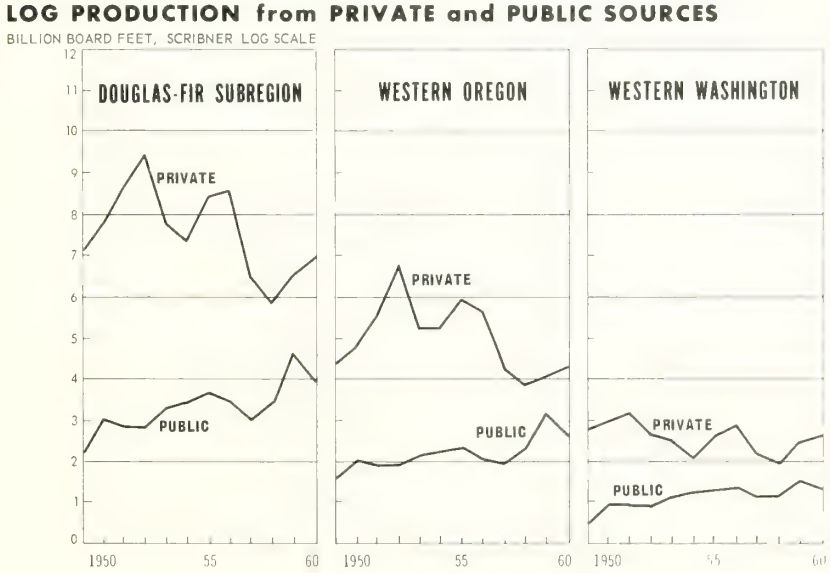


Figure 17.—Distribution of annual log production between public and private sources in the Douglas-fir subregion, 1949-60.

## Table 19. — Log production in Douglas-fir subregion by ownership class and State, 1949-60

| Year | Oregon | | | | Washington | | | | Douglas-fir subregion | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Public | Private | Total | Percent public | Public | Private | Total | Percent public | Public | Private | Total | Percent public |
| | — MM bd. ft., Scribner log scale — | | | | — MM bd. ft., Scribner log scale — | | | | — MM bd. ft., Scribner log scale — | | | |
| 1949 | 1,596 | 4,357 | 5,953 | 26.8 | 525 | 2,783 | 3,308 | 15.8 | 2,121 | 7,140 | 9,261 | 22.9 |
| 1950 | 2,039 | 4,767 | 6,806 | 30.0 | 977 | 2,976 | 3,953 | 24.7 | 3,016 | 7,743 | 10,759 | 28.0 |
| 1951 | 1,891 | 5,522 | 7,413 | 25.5 | 976 | 3,151 | 4,127 | 23.6 | 2,867 | 8,673 | 11,540 | 24.8 |
| 1952 | 1,915 | 6,750 | 8,665 | 22.1 | 927 | 2,656 | 3,583 | 25.9 | 2,842 | 9,406 | 12,248 | 23.2 |
| 1953 | 2,113 | 5,230 | 7,343 | 28.8 | 1,177 | 2,513 | 3,690 | 31.9 | 3,290 | 7,743 | 11,033 | 29.8 |
| 1954 | 2,214 | 5,224 | 7,438 | 29.8 | 1,226 | 2,089 | 3,315 | 37.0 | 3,440 | 7,313 | 10,753 | 32.0 |
| 1955 | 2,341 | 5,862 | 8,203 | 28.5 | 1,296 | 2,596 | 3,892 | 33.3 | 3,637 | 8,458 | 12,095 | 30.1 |
| 1956 | 2,086 | 5,627 | 7,713 | 27.0 | 1,349 | 2,919 | 4,268 | 31.6 | 3,435 | 8,546 | 11,981 | 28.7 |
| 1957 | 1,945 | 4,252 | 6,197 | 31.4 | 1,124 | 2,173 | 3,297 | 34.1 | 3,069 | 6,425 | 9,494 | 32.3 |
| 1958 | 2,310 | 3,900 | 6,210 | 37.2 | 1,148 | 1,960 | 3,108 | 36.9 | 3,458 | 5,860 | 9,318 | 37.1 |
| 1959 | 3,138 | 4,082 | 7,220 | 43.5 | 1,494 | 2,472 | 3,966 | 37.7 | 4,632 | 6,554 | 11,186 | 41.4 |
| 1960 | 2,595 | 4,334 | 6,929 | 37.4 | 1,286 | 2,603 | 3,889 | 33.1 | 3,881 | 6,937 | 10,818 | 35.9 |

The harvest from public lands in western Oregon remained relatively stable from 1950 to 1957, averaging 2.1 billion feet. This was largely due to decline in the salvage harvest on State and county lands on the Tillamook Burn in northwestern Oregon as the harvest from other public lands increased. From 1958 to 1960, the average annual cut on public lands increased to 2.7 billion feet, approximately 38 percent of the total log harvest in western Oregon.

The greatest increase in public log harvest came in southwestern Oregon. From the 1950-52 average of 869 million board feet, it increased to 1,742 million feet in the years of 1958-60. This increase of 873 million board feet was nearly double the increase in public harvest in all of western Washington. In northwestern Oregon, the public harvest has consistently averaged a billion board feet per year.

Table 20. — Percent of total log production from public lands, 1950-60

| Area | 1950-52 | 1953-56 | 1957-60 |
|---|---|---|---|
| Western Washington | 24.7 | 33.3 | 35.4 |
| Puget Sound | 21.6 | 33.4 | 33.9 |
| Southwestern Washington | 30.1 | 34.1 | 37.7 |
| Western Oregon | 25.6 | 28.5 | 37.7 |
| Northwestern Oregon | 36.4 | 34.5 | 37.9 |
| Southwestern Oregon | 18.6 | 25.2 | 37.5 |
| Douglas-fir subregion | 25.3 | 30.1 | 36.9 |

Tables 21 and 22 show the distribution of the public harvest by public ownership class and subareas.

## Table 21.—Log production in western Washington by ownership class and subareas, 1949-60

| Subarea and year | Forest Service | State forests[1] | Other public[2] | All Public | Private and other | Total | Forest Service | State forests and other public | All public |
|---|---|---|---|---|---|---|---|---|---|
| | Million board feet, Scribner log scale | | | | | | Percent | | |
| Puget Sound: | | | | | | | | | |
| 1949 | 232 | 11 | 38 | 281 | 1,814 | 2,095 | 11.1 | 2.3 | 13.4 |
| 1950 | 333 | 126 | 38 | 497 | 1,973 | 2,470 | 13.5 | 6.6 | 20.1 |
| 1951 | 382 | 111 | 37 | 530 | 2,041 | 2,571 | 14.9 | 5.8 | 20.6 |
| 1952 | 412 | 121 | 37 | 570 | 1,793 | 2,363 | 17.4 | 6.7 | 24.1 |
| 1953 | 524 | 187 | 39 | 750 | 1,501 | 2,251 | 23.3 | 10.0 | 33.3 |
| 1954 | 487 | 289 | 27 | 803 | 1,264 | 2,067 | 23.6 | 15.3 | 38.8 |
| 1955 | 450 | 257 | 53 | 760 | 1,591 | 2,351 | 19.1 | 13.2 | 32.3 |
| 1956 | 436 | 297 | 11 | 744 | 1,729 | 2,473 | 17.6 | 12.5 | 30.1 |
| 1957 | 432 | 166 | 13 | 611 | 1,367 | 1,978 | 21.8 | 9.1 | 30.9 |
| 1958 | 505 | 99 | 15 | 619 | 1,189 | 1,808 | 27.9 | 6.3 | 34.2 |
| 1959 | 716 | 164 | 2 | 882 | 1,571 | 2,453 | 29.2 | 6.8 | 36.0 |
| 1960 | 605 | 166 | 23 | 794 | 1,538 | 2,332 | 25.9 | 8.1 | 34.0 |
| Southwestern Washington: | | | | | | | | | |
| 1949 | 190 | 8 | 45 | 243 | 969 | 1,212 | 15.7 | 4.4 | 20.0 |
| 1950 | 235 | 193 | 51 | 479 | 1,003 | 1,482 | 15.9 | 16.5 | 32.3 |
| 1951 | 245 | 132 | 68 | 445 | 1,110 | 1,555 | 15.8 | 12.9 | 28.6 |
| 1952 | 227 | 41 | 89 | 357 | 863 | 1,220 | 18.6 | 10.7 | 29.3 |
| 1953 | 217 | 112 | 98 | 427 | 1,012 | 1,439 | 15.1 | 14.6 | 29.7 |
| 1954 | 242 | 81 | 99 | 422 | 825 | 1,247 | 19.4 | 14.4 | 33.8 |
| 1955 | 239 | 153 | 144 | 536 | 1,006 | 1,542 | 15.5 | 19.3 | 34.8 |
| 1956 | 291 | 198 | 115 | 604 | 1,190 | 1,794 | 16.2 | 17.4 | 33.7 |
| 1957 | 240 | 207 | 66 | 513 | 806 | 1,319 | 18.2 | 20.7 | 38.9 |
| 1958 | 271 | 187 | 70 | 528 | 771 | 1,299 | 20.9 | 19.8 | 40.6 |
| 1959 | 392 | 103 | 117 | 612 | 901 | 1,513 | 25.9 | 14.5 | 40.4 |
| 1960 | 304 | 88 | 100 | 492 | 1,065 | 1,557 | 19.5 | 12.1 | 31.6 |

[1] Years 1949-54 based on timber sold.

[2] Indian lands, National Parks, Bureau of Land Management.

Source: Log production reports for the years 1949-60, published by Pacific Northwest Forest and Range Experiment Station.

## Table 22. — Log production in western Oregon by ownership class and subareas, 1949-60

| Subarea and year | Forest Service | Bureau of Land Mangt.[1] | State forests[2] | Other public | All public | Private | Total | Forest Service | Bureau of Land Mangt. | State forests and other public | All public |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Million board feet, Scribner log scale | | | | | | | Percent | | | |
| Northwestern Oregon: | | | | | | | | | | | |
| 1949 | 178 | 41 | 761 | 14 | 994 | 1,839 | 2,833 | 6.3 | 1.4 | 27.4 | 35.1 |
| 1950 | 214 | 77 | 816 | 29 | 1,136 | 1,726 | 2,862 | 7.5 | 2.7 | 29.5 | 39.7 |
| 1951 | 244 | 91 | 714 | 19 | 1,068 | 1,734 | 2,802 | 8.7 | 3.2 | 26.2 | 28.1 |
| 1952 | 310 | 104 | 606 | 14 | 1,034 | 2,202 | 3,236 | 9.6 | 3.2 | 19.2 | 32.0 |
| 1953 | 400 | 99 | 531 | 1 | 1,031 | 1,775 | 2,806 | 14.3 | 3.5 | 18.9 | 36.7 |
| 1954 | 379 | 144 | 467 | 1 | 991 | 1,639 | 2,630 | 14.4 | 5.5 | 17.8 | 37.7 |
| 1955 | 413 | 155 | 440 | -- | 1,008 | 1,887 | 2,895 | 14.3 | 5.3 | 15.2 | 34.8 |
| 1956 | 409 | 109 | 350 | -- | 868 | 2,205 | 3,073 | 13.3 | 3.5 | 11.4 | 28.2 |
| 1957 | 373 | 157 | 291 | -- | 821 | 1,546 | 2,367 | 15.8 | 6.6 | 12.3 | 34.7 |
| 1958 | 509 | 153 | 103 | -- | 765 | 1,417 | 2,182 | 23.3 | 7.0 | 4.7 | 35.0 |
| 1959 | 768 | 228 | 111 | -- | 1,107 | 1,453 | 2,560 | 30.0 | 8.9 | 4.3 | 43.2 |
| 1960 | 614 | 192 | 138 | -- | 944 | 1,379 | 2,323 | 26.4 | 8.3 | 5.9 | 40.6 |
| Southwestern Oregon: | | | | | | | | | | | |
| 1949 | 346 | 222 | 22 | 12 | 602 | 2,519 | 3,121 | 11.1 | 7.1 | .1 | 19.3 |
| 1950 | 554 | 326 | 14 | 9 | 903 | 3,041 | 3,944 | 14.0 | 8.3 | .6 | 22.9 |
| 1951 | 558 | 256 | 10 | -- | 824 | 3,788 | 4,612 | 12.1 | 5.6 | .2 | 17.9 |
| 1952 | 597 | 282 | 2 | -- | 881 | 4,548 | 5,429 | 11.0 | 5.2 | -- | 16.2 |
| 1953 | 637 | 442 | 3 | -- | 1,082 | 3,455 | 4,537 | 14.0 | 9.7 | .1 | 23.8 |
| 1954 | 790 | 428 | 5 | -- | 1,223 | 3,585 | 4,808 | 16.4 | 8.9 | .1 | 25.4 |
| 1955 | 800 | 529 | 3 | -- | 1,332 | 3,975 | 5,307 | 15.1 | 10.0 | -- | 25.1 |
| 1956 | 804 | 410 | 4 | -- | 1,218 | 3,422 | 4,640 | 17.3 | 8.8 | .1 | 26.2 |
| 1957 | 699 | 414 | 11 | -- | 1,124 | 2,707 | 3,831 | 18.2 | 10.8 | .3 | 29.3 |
| 1958 | 963 | 570 | 13 | -- | 1,546 | 2,483 | 4,029 | 23.9 | 14.1 | .3 | 38.4 |
| 1959 | 1,301 | 704 | 25 | -- | 2,030 | 2,629 | 4,659 | 27.9 | 15.1 | .5 | 43.6 |
| 1960 | 996 | 622 | 33 | -- | 1,651 | 2,956 | 4,607 | 21.6 | 13.5 | .7 | 35.8 |

[1] Data for 1949-55 from Bureau of Land Management.

[2] Data for 1949-57 from estimates provided by Office of State Forester, Salem, Oregon.

Source: Log production reports for the years 1949-60, published by Pacific Northwest Forest and Range Experiment Station.

# Relationship of Log Production to Total Forest Industry Capacity, 1945-60

Some of the highlights of relationships between log production and forest industry capacity have been introduced in the preceding discussions of the lumber, plywood, and pulp industries. Here, the relationships between log production and industrial capacity during the postwar period are brought together and generalized for the lumber, plywood, and pulp industries collectively.

Because log consumption in the pulp industry remained essentially constant during the postwar expansion of pulp capacity, it is easiest handled analytically by subtracting pulp log consumption from total log production. Accordingly, log production figures in table 18 are reduced to a saw log and peeler log production basis by subtracting log and farmer wood consumption for pulp as reported as in table 13. The subtraction is made at the rate of 500 board feet of log production per cord of pulpwood. Oregon pulp log consumption is attributed entirely to northwestern Oregon. For the years that pulp log consumption is lacking, the average of reported years is used as the best estimate. For convenience in exposition, the term "log production," as used in this section, includes saw log and peeler log production only.

## Subregion's Log Production Consistently Below Lumber and Plywood Capacity

Since 1946, annual log production in the Douglas-fir subregion has been consistently below the installed annual log input capacity of the lumber and plywood industries (fig. 18, table 23). The excess of lumber and plywood capacity over log production was greatest in the recession years: 1949, 1953-54, 1957-58, and 1960. In these years, it averaged 2.3 billion board feet, log scale, or 21.6 percent of the installed capacity. Most of the excess in these years was attributable to cyclical declines in lumber production.

In the most favorable years, the excess averaged 1.0 billion board feet, log scale, only 43 percent as much as that in the recession years.

Table 23. — Relation of log production to lumber and plywood log input capacity in the Douglas-fir subregion, 1945-60

| Year | Lumber and plywood capacity | Plywood and sawmill log production | Capacity in excess of log production | |
|---|---|---|---|---|
| | | | Amount | Proportion of capacity |
| | MM bd. ft., Scribner log scale | MM bd. ft., Scribner log scale | MM bd. ft., Scribner log scale | Percent |
| 1945 | -- | 5,980 | -- | -- |
| 1946 | 8,113 | 7,111 | 1,002 | 12.4 |
| 1947 | 9,202 | -- | -- | -- |
| 1948 | 9,708 | 9,032 | 676 | 7.0 |
| 1949 | 9,833 | 7,575 | 2,258 | 23.0 |
| 1950 | 10,266 | 9,073 | 1,193 | 11.6 |
| 1951 | 11,122 | 9,728 | 1,394 | 12.5 |
| 1952 | 11,175 | 10,661 | 514 | 4.6 |
| 1953 | 10,767 | 9,347 | 1,420 | 13.2 |
| 1954 | 10,689 | 9,067 | 1,622 | 15.2 |
| 1955 | 11,480 | 10,409 | 1,071 | 9.3 |
| 1956 | 11,001 | 10,103 | 898 | 8.2 |
| 1957 | 10,842 | 7,395 | 3,447 | 31.8 |
| 1958 | 10,693 | 7,808 | 2,885 | 27.0 |
| 1959 | 10,976 | 9,650 | 1,326 | 12.1 |
| 1960 | 11,392 | 9,202 | 2,190 | 19.2 |

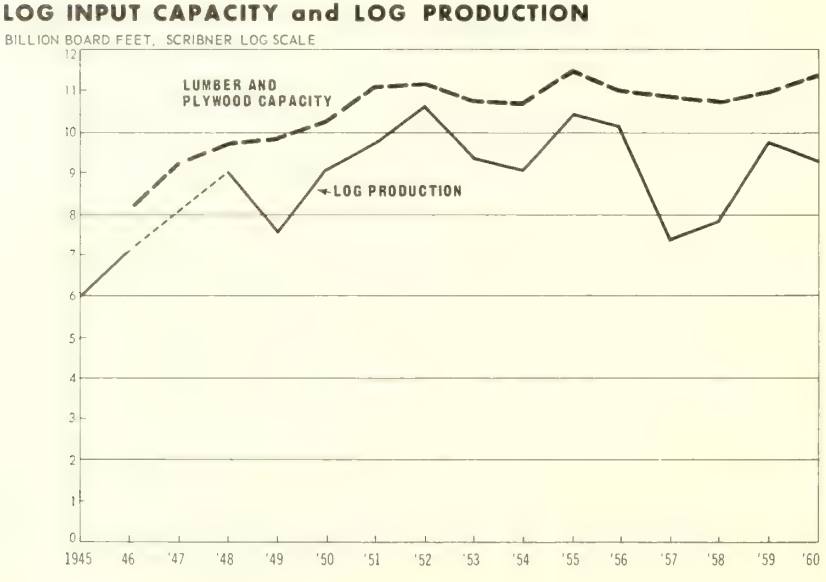


Figure 18.—Annual lumber and plywood log input capacity and saw log and peeler log production in the Douglas-fir subregion, 1945-60.

## Log Production Increases More Than Industrial Capacity, 1946-52

From 1946 to 1952, log production in the subregion increased 3.6 billion board feet, log scale, 0.5 billion feet more than the expansion of lumber and plywood capacity as measured in log input units (table 23). Unused capacity in 1952, moreover, dropped to 0.5 billion board feet, log scale (table 23), the lowest level experienced by the lumber and plywood industries in the postwar period. Most of the industrial expansion in this period came in lumber production, largely in response to the rapid rise in lumber demand after the war.

## Expansion of Capacity Stops in Subregion and Log Production Declines

Expansion of the combined lumber and plywood capacity stopped abruptly in 1952 and remained practically stable at 11 billion board feet, log scale, thereafter. In this period of stable capacity, however, plywood capacity continued to expand while lumber capacity declined in nearly equal amount. This leveling off of lumber and plywood capacity appears to have been largely a response to the log supply situation in the Douglas-fir subregion. Log production declined more or less steadily after 1952.

## Stumpage Price Rise After 1952 Fails to Halt Log Production Decline

Rising stumpage prices to 1956 and their relatively high level to 1960 (fig. 19) failed to halt the decline in log production after 1952. The stumpage price increase from 1947 to 1952 was largely associated with increased demand for logs to meet the requirements of the expanding forest products industry in that period. The increase in stumpage prices after 1952, however, is associated with an increase in the proportions and absolute amount of the subregion's log production consumed in the plywood industry.

## Western Washington's Capacity Fails to Increase in Early Postwar Years

While lumber and plywood capacity in the subregion expanded in the postwar years to 1952, it remained relatively stable in western Washington, averaging 3.7 billion board feet, log scale, with an average deviation of only 2.2 percent (fig. 20). In this period, western Washington plants were partially dependent upon log imports from other areas, largely western Oregon, where log production exceeded installed capacity to 1952 (fig. 20). From 1946 to 1952, western Washington's installed capacity averaged 1.4 billion feet, log scale, more than its log production. Unused

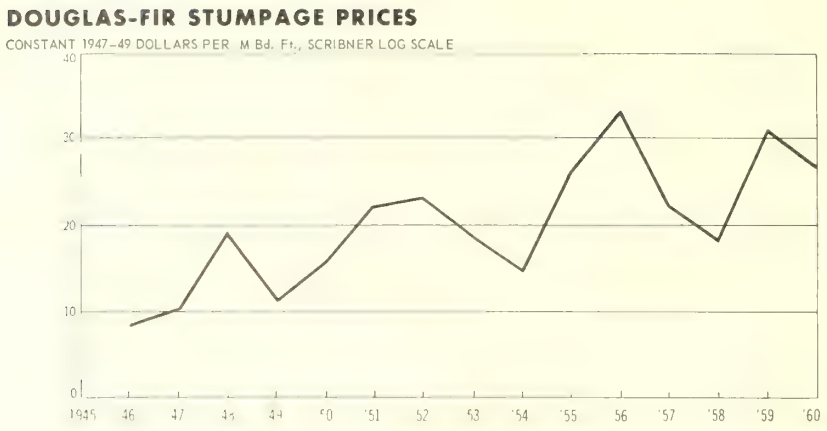


Figure 19.—Douglas-fir stumpage prices in the Douglas-fir subregion, 1946-60.

Source: Table 4 of "The Demand and Price Situation for Forest Products." U. S. Forest Serv. and Agr. Stabilization Conserv. Serv., 47 pp., illus. 1961.

lumber and plywood capacity, on the other hand, averaged only 0.8 billion feet log scale. After 1952, plant capacity in western Washington gradually declined, adjusting more closely to actual log production (fig. 20). This adjustment probably was in part a response to a tightening log supply situation in the 1950 decade in which western Oregon mills continued to expand capacity relative to log production.

## Western Oregon's Log Production and Capacity Determine Subregion Trends

The general trends in log production and lumber and plywood capacity in the subregion in the postwar period were determined largely by developments in western Oregon (figs. 18 and 20 and table 24). Changes in log production and capacity in western Washington were relatively small by comparison.

From 1946 to 1955, the combined lumber and plywood capacity in western Oregon increased 3.5 billion board feet, log scale. Until 1952, the expansion was due, as for the subregion, almost entirely to the growth of the lumber industry. From 1952 to 1955, the net expansion was attributable entirely to the plywood industry; lumber capacity remained about the same in these years (fig. 11).

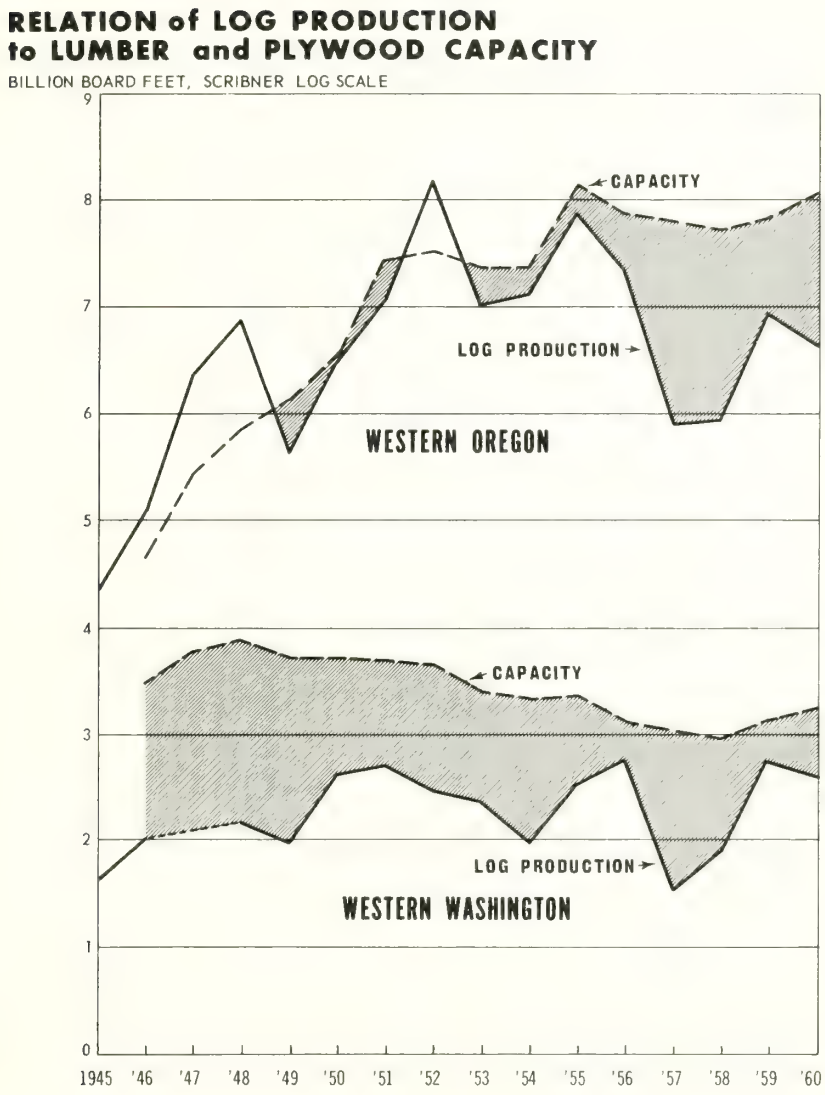


Figure 20.—Relation of log production to lumber and plywood capacity in western Washington and western Oregon, 1945-60.

Table 24. — Comparison of log production with lumber and plywood log input capacity in western Washington and western Oregon, 1945-60

| Year | Lumber and plywood capacity | Plywood and sawmill log production | Capacity in excess of log production[1] | |
|---|---|---|---|---|
| | MM bd. ft., Scribner log scale | MM bd. ft., Scribner log scale | MM bd. ft., Scribner log scale | Percent |
| Western Washington: | | | | |
| 1945 | -- | 1,631 | -- | -- |
| 1946 | 3,463 | 2,015 | 1,448 | 41.8 |
| 1947 | 3,789 | -- | -- | -- |
| 1948 | 3,875 | 2,166 | 1,709 | 44.1 |
| 1949 | 3,704 | 1,960 | 1,744 | 47.1 |
| 1950 | 3,709 | 2,605 | 1,104 | 29.8 |
| 1951 | 3,680 | 2,681 | 999 | 27.1 |
| 1952 | 3,656 | 2,476 | 1,180 | 32.3 |
| 1953 | 3,401 | 2,342 | 1,059 | 31.1 |
| 1954 | 3,323 | 1,967 | 1,356 | 40.8 |
| 1955 | 3,357 | 2,544 | 813 | 24.2 |
| 1956 | 3,115 | 2,762 | 353 | 11.3 |
| 1957 | 3,033 | 1,515 | 1,518 | 50.0 |
| 1958 | 2,964 | 1,875 | 1,089 | 36.7 |
| 1959 | 3,135 | 2,718 | 417 | 13.3 |
| 1960 | 3,248 | 2,581 | 667 | 20.5 |
| Western Oregon: | | | | |
| 1945 | -- | 5,349 | -- | -- |
| 1946 | 4,650 | 5,096 | (446) | (9.6) |
| 1947 | 5,413 | 6,369 | (956) | (17.7) |
| 1948 | 5,833 | 6,866 | (1,033) | (17.7) |
| 1949 | 6,129 | 5,615 | 514 | 8.4 |
| 1950 | 6,557 | 6,468 | 89 | 1.4 |
| 1951 | 7,443 | 7,046 | 397 | 5.3 |
| 1952 | 7,519 | 8,185 | (666) | (8.9) |
| 1953 | 7,369 | 7,005 | 364 | 4.9 |
| 1954 | 7,366 | 7,100 | 266 | 3.6 |
| 1955 | 8,122 | 7,865 | 257 | 3.2 |
| 1956 | 7,885 | 7,341 | 544 | 6.9 |
| 1957 | 7,810 | 5,880 | 1,930 | 24.7 |
| 1958 | 7,729 | 5,933 | 1,796 | 23.2 |
| 1959 | 7,840 | 6,932 | 908 | 11.6 |
| 1960 | 8,055 | 6,621 | 1,434 | 17.8 |

[1]Parentheses indicate excess of log production over lumber and plywood capacity.

As can be seen from figure 20 and table 25, capacity and log production expanded more or less together in western Oregon until 1952. Log production averaged 102 percent of capacity, exceeding or very nearly equaling it in individual years.

From 1955 to 1960, log production in western Oregon declined 1.2 billion board feet. In the same period, growth in capacity essentially ceased. Although lumber capacity declined, growth in plywood capacity tended to offset lumber capacity reductions (fig. 11).

Table 25. — Comparison of log production with lumber and plywood log input capacity in northwestern and southwestern Oregon, 1945-60

| Year | Northwestern Oregon | | | | Southwestern Oregon | | | |
|---|---|---|---|---|---|---|---|---|
| | Lumber and plywood capacity | Plywood and sawmill log production | Capacity in excess of log production[1] | | Lumber and plywood capacity | Plywood and sawmill log production | Capacity in excess of log production[1] | |
| | MM bd. ft., Scribner log scale | MM bd. ft., Scribner log scale | MM bd. ft., Scribner log scale | Percent | MM bd. ft., Scribner log scale | MM bd. ft., Scribner log scale | MM bd. ft., Scribner log scale | Percent |
| 1945 | -- | 2,004 | -- | -- | -- | 2,345 | -- | -- |
| 1946 | 2,180 | 2,300 | (120) | (5.5) | 2,471 | 2,760 | (289) | (11.7) |
| 1947 | 2,415 | 3,080 | (665) | (27.5) | 2,996 | 3,289 | (293) | (9.8) |
| 1948 | 2,659 | 2,990 | (331) | (12.4) | 3,173 | 3,876 | (703) | (22.2) |
| 1949 | 2,806 | 2,494 | 312 | 11.1 | 3,323 | 3,121 | 202 | 6.1 |
| 1950 | 3,009 | 2,525 | 484 | 16.1 | 3,548 | 3,943 | (395) | (11.1) |
| 1951 | 3,315 | 2,434 | 881 | 26.6 | 4,128 | 4,612 | (484) | (11.7) |
| 1952 | 3,215 | 2,756 | 459 | 14.3 | 4,304 | 5,429 | (1,125) | (26.1) |
| 1953 | 3,231 | 2,468 | 763 | 23.6 | 4,138 | 4,537 | (399) | (9.6) |
| 1954 | 3,080 | 2,292 | 788 | 25.6 | 4,286 | 4,808 | (522) | (12.2) |
| 1955 | 3,256 | 2,557 | 699 | 21.5 | 4,866 | 5,308 | (442) | (9.1) |
| 1956 | 3,107 | 2,700 | 407 | 13.1 | 4,778 | 4,641 | 137 | 2.9 |
| 1957 | 3,131 | 2,049 | 1,082 | 34.5 | 4,679 | 3,831 | 848 | 18.1 |
| 1958 | 3,007 | 1,905 | 1,102 | 36.6 | 4,722 | 4,028 | 694 | 14.7 |
| 1959 | 3,220 | 2,272 | 948 | 29.4 | 4,620 | 4,660 | (40) | (0.9) |
| 1960 | 3,180 | 2,014 | 1,166 | 36.7 | 4,875 | 4,607 | 268 | 5.5 |

[1] Parentheses indicate excess of log production over lumber and plywood log input capacity.

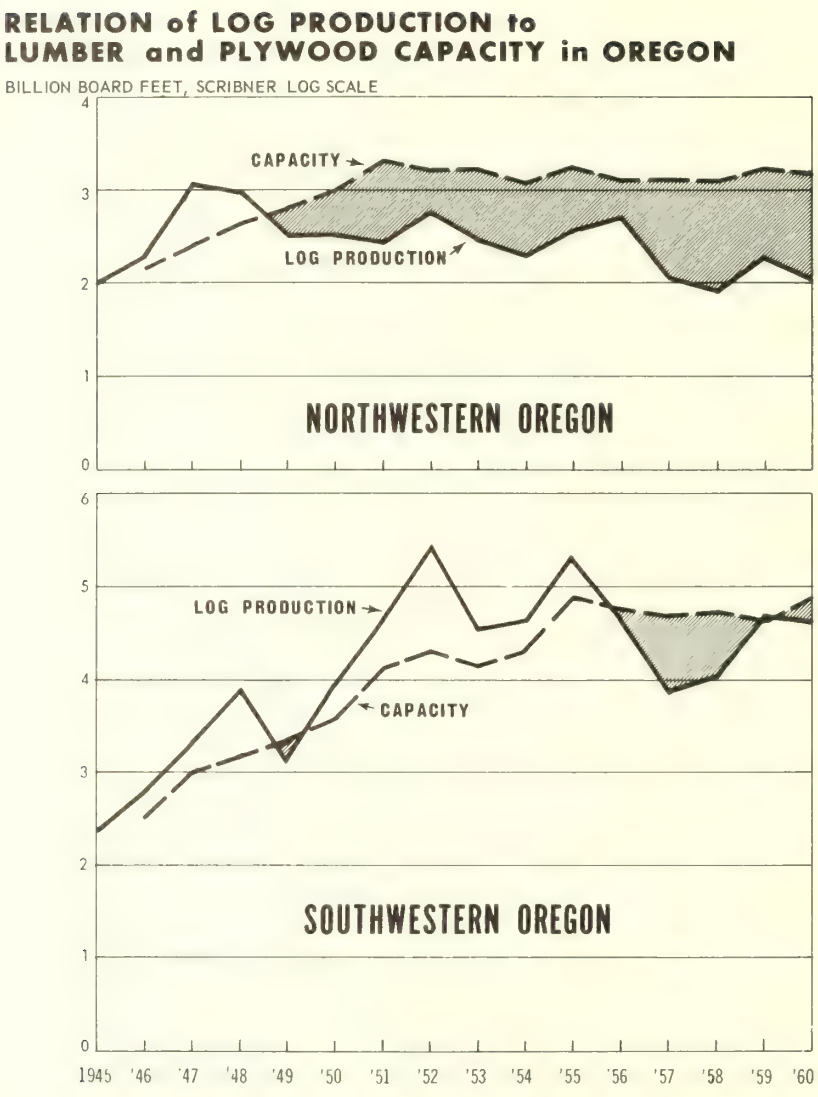


Figure 21.—Relation of log production to lumber and plywood capacity in northwestern and southwestern Oregon, 1945-60.

## Log Production Declines and Capacity Expansion Halts After 1948 in Northwestern Oregon

In northwestern Oregon, annual log production exceeded lumber and plywood capacity to 1949 (fig. 21, table 25). When log production turned downward after 1948, expansion of capacity leveled off sharply beginning in 1951. Plywood capacity, however, continued to replace lumber capacity (fig. 11).

From 1951 to 1956, capacity exceeded log production by an average of 666 million board feet, log scale. In this period, it is probable that northwestern Oregon mills obtained part of their log requirements from southwestern Oregon, where annual log production averaged 445 million board feet more than installed capacity from 1946 to 1955 (fig. 21, table 25).

After 1956, unused capacity in northwestern Oregon increased to an average of 1,075 million board feet, log scale, or 34 percent of installed capacity. In southwestern Oregon, by contrast, it averaged only 443 million feet, or 9 percent.

## Southwestern Oregon's Capacity Expansion Also Halts and Log Production Declines

While log production exceeded installed capacity in southwestern Oregon, capacity continued to expand. Log production fell after 1955 and expansion of capacity halted sharply, as they had in northwestern Oregon in 1951 (fig. 21, table 25). Elsewhere in the West, as stated before, lumber production continued to expand to 1959. Stumpage prices in the subregion were at their highest historical level.

# Outlook for Log Production and Industrial Capacity After 1960

Log supplies in the next decade will be a critical factor in determining lumber and plywood capacity and production in the subregion. There is no important evidence which indicates that log supply will be a significant problem for the pulp industry in the 1960's even though capacity continues to expand.

## Allowable Cut on Lands in Public Ownership Was 4.6 Billion Feet in 1960

For the Douglas-fir subregion the 1960 allowable cut on public lands was 4.6 billion board feet, plus a nonchargeable cut[12] of 0.3 billion feet. The distribution of the allowable cut, including the nonchargeable volume, is presented by subarea and public agency in table 26.

Table 26. — Distribution of allowable cut by subarea and public agency, 1960[1]

| Subarea | Forest Service | O&C lands | Public domain | Indian lands | State and other public lands | Total public |
|---|---|---|---|---|---|---|
| | Million board feet, Scribner log scale | | | | | |
| Puget Sound | 725.3 | -- | -- | 21.2 | 396.4 | 1,142.9 |
| Southwestern Washington | 446.3 | -- | -- | 106.0 | 195.0 | 747.3 |
| Western Washington | 1,171.6 | -- | -- | 127.2 | 591.4 | 1,890.2 |
| Northwestern Oregon | 661.4 | 203.9 | 49.5 | -- | 95.9 | 1,010.7 |
| Southwestern Oregon | 1,140.0 | 754.5 | 35.5 | -- | 62.9 | 1,992.9 |
| Western Oregon | 1,801.4 | 958.4 | 85.0 | -- | 158.8 | 3,003.6 |
| Douglas-fir subregion | 2,973.0 | 958.4 | 85.0 | 127.2 | 750.2 | 4,893.8 |

[1] Includes nonchargeable volume on basis of past experience. The volumes shown in this table are in terms of utilization standards and units of measure used in the industry today. They are not necessarily the same as those used in showing depletion of the forest inventory growing stock by these public agencies.

[12] For the Bureau of Land Management, the nonchargeable cut is estimated from their current experience, which is 11.6 percent of the current allowable cut. The Bureau expects this figure to increase to 14.3 percent by 1970. For all other public ownerships, the nonchargeable cut was estimated at 6 percent of their allowable cut, the average experience of National Forests in recent years.

## Log Production from Public Lands Expected to Increase [13]

In its longer range program for National Forests, the Forest Service in 1961 announced a harvest goal of 3.0 billion feet in Oregon and 1.6 billion feet in Washington for the year 1972.[14] Prorating this increase in proportion to the 1960 allowable cuts for the east-side and west-side forests would indicate an allowable cut of 3.6 billion board feet by 1972 on National Forests in the Douglas-fir subregion. This is about 0.6 billion feet or 20 percent more than the 1960 allowable cut.

On October 15, 1962, the allowable cut on National Forests in the subregion was raised 258 million board feet, to 3.2 billion feet, or 9 percent above the 1960 allowable cut.

Similar increases on other public lands above the 1960 levels would indicate an allowable cut of 5.9 billion feet by 1972 for all public lands combined, or 1 billion feet more than in 1960.[15] For the remainder of the 1960's the average allowable cut is estimated at 5.4 billion feet, a 10-percent increase over 1960, to permit gradual attainment of the increase estimated for 1972.

The allowable cut on public forest lands has shown a continuing upward trend to the present. From 1950 to 1960, for example, the increase in the Douglas-fir subregion was approximately 50 percent. This came largely as a result of improved inventories and growth data, closer utilization standards, and shorter rotations. Further increases in allowable cut to 1972 are expected to come in large measure from thinnings in young-growth and prelogging and salvage in old-growth timber.

## Private Timber Harvest Expected to Decline in Subregion

Private log production in the Douglas-fir subregion is estimated at 6.7 billion feet for the 1960's. This corresponds to the following cutting rates for private lands:

| Subarea | Percent of inventory harvested |
|---|---|
| Puget Sound | 2.4 |
| Southwestern Washington | 2.8 |
| Northwestern Oregon | 2.8 |
| Southwestern Oregon | 4.0 |

[13] Log production hereinafter includes pulp logs.

[14] See pp. 29 and 38 of: U. S. Forest Service. A development program for the National Forests; estimates of work needed and costs by States. 42 pp. 1961.

[15] On Bureau of Land Management lands in western Oregon, the allowable cut in 1962, including nonchargeable volume, was estimated at 1,258 million board feet, or 31 percent more than in 1960.

The projected cut of 6.7 billion feet constitutes a 1-billion-board-foot decline in private log production in the 1960's from the average for the 1950's, but about 5 percent more than the average for 1957 to 1960. It is about 55 percent of the total prospective harvest for the subregion, compared with 63 percent of the total cut in the subregion in the years 1957 to 1960 (table 20). Table 27 sets out the details of the public and private log harvest outlook by subareas for the 1960's.

Table 27. — Comparison of the prospective log harvest in the 1960's with the 1960 installed forest industry capacity

| Area | Allowable cut on public lands, 1960's | Prospective private log harvest, 1960's | Total prospective log harvest, 1960's | Installed capacity 1960 |
|---|---|---|---|---|
| | — — — — — — Billion board feet, Scribner log scale — — — — — — | | | |
| Puget Sound | 1.2 | 1.8 | 3.0 | 2.8 |
| Southwestern Washington | .9 | .9 | 1.8 | 1.8 |
| Western Washington | 2.1 | 2.7 | 4.8 | [1]4.6 |
| Northwestern Oregon | 1.1 | 1.7 | 2.8 | [2]3.5 |
| Southwestern Oregon | 2.2 | 2.3 | 4.5 | 4.9 |
| Western Oregon | 3.3 | 4.0 | 7.3 | 8.4 |
| Subregion total | 5.4 | 6.7 | 12.1 | 13.0 |

[1] Includes 1.4 billion board feet of logs for pulpmill consumption. This is divided equally between Puget Sound and southwestern Washington since pulp capacity is distributed about equally between these subareas.
[2] Includes 0.3 billion feet of logs for pulpmills.

## Subregion's Prospective Log Harvest About 1 Billion Feet More Than Average Cut in 1959 and 1960

The average annual prospective log harvest for the 1960's is estimated at 12.1 billion board feet for the Douglas-fir subregion. It is 1.1 billion feet more than the average cut of 11.0 billion feet for 1959 and 1960.

Almost all, 0.9 billion feet, of the projected additional cut is in western Washington. About 0.5 billion feet arises from the deficit between the actual cut and the allowable cut on all public lands in 1959 and 1960 (table 28). An additional 0.2 billion feet is attributable to the projected increase in allowable cut on public lands during the 1960's. The balance is due to a net increase in the private timber harvest. This arises from a favorable relation of growth rates to cutting rates and an assumed increase in intensity of management and utilization of second-growth timber.

The 0.2 billion feet increase in the prospective log harvest for western Oregon in the 1960's over the average 1959-60 cut is attributable entirely to increases in the projected allowable cut for public lands.

Table 28. — Relationship of the 1960 allowable cut to the 1959-60 actual cut on public lands

| Area | 1960 allowable cut[1] | Average 1959-60 annual log harvest | Difference from allowable cut | Difference in percent of allowable cut |
|---|---|---|---|---|
| | — — Million board feet, Scribner log scale — — | | | Percent |
| Puget Sound: | | | | |
| Forest Service | 725 | 660 | -65 | -9.0 |
| Other public | 418 | 178 | -240 | -57.4 |
| Southwestern Washington: | | | | |
| Forest Service | 446 | 348 | -98 | -22.0 |
| Other public | 301 | 204 | -97 | -32.2 |
| Northwestern Oregon: | | | | |
| Forest Service | 661 | 691 | +30 | +4.5 |
| O&C and public domain | 253 | 210 | -43 | -17.0 |
| Other public | 96 | 124 | +28 | +29.2 |
| Southwestern Oregon: | | | | |
| Forest Service | 1,140 | 1,149 | +9 | +.8 |
| O&C and public domain | 790 | 663 | -127 | -16.1 |
| Other public | 63 | 29 | -34 | -54.0 |
| Douglas-fir subregion | 4,894 | 4,256 | [2]-638 | -13.0 |

[1] Includes nonchargeable cut.
[2] Fifty-four percent of the unused allowable cut occurred on non-Federal lands. The balance was distributed on lands administered by the Forest Service (19 percent) and Bureau of Land Management (27 percent).

## Subregion's Prospective Log Harvest Nearly 1 Billion Feet Less Than Installed Capacity in 1960

As can be seen from table 27, the total installed capacity of plants in the Douglas-fir subregion in 1960 exceeded the prospective average log harvest in the decade of the 1960's by 0.9 billion board feet, log scale, or 7 percent of the 1960 capacity. This is appreciably lower than the average surplus of 14.8 percent during 1946-60 (table 23).

## Subregion's Surplus Capacity Concentrated In Western Oregon

In 1960, the installed plant capacity in western Oregon was 8.4 billion feet, log scale, including 0.3 billion feet of logs for pulpwood purposes. The prospective log harvest for the 1960's is 7.3 billion board feet, log scale, about the same as in the 1950's, but 1.1 billion feet (13 percent) less than the installed capacity. Most of the excess, or 700 million feet, is in northwestern Oregon. The balance, 400 million feet, is in southwestern Oregon. The excess capacity in western Oregon is greater than that for the subregion due to a surplus of 200 million feet in the prospective log harvest for western Washington in the 1960's.

Pulp capacity is expected to expand, but it is believed unlikely that demand for pulp logs will have a serious impact on saw log or peeler log production. Recent trends suggest further reduction in lumber capacity and increasing plywood plant capacity.

## Prospective Log Harvest in Western Washington Close to Present Capacity

In western Washington, the estimated installed capacity of the lumber, plywood, and pulp industries in 1960 was 4.6 billion board feet, log scale. This included 1.4 billion feet of logs for pulpwood, the average log consumption by the western Washington pulp industry from 1956 to 1960. The prospective log harvest for the 1960's is estimated at 4.8 billion board feet, log scale. This nearly equals the 1960 installed capacity. The situation is about the same for the Puget Sound and southwestern Washington subareas.

It is contemplated that the capacity of older sawmills originally designed for old-growth timber will decline further in western Washington. New sawmills better adapted to processing second-growth timber should eventually replace and in time expand existing lumber capacity. It is anticipated that plywood capacity in western Washington will remain relatively stable. Pulp capacity, it seems, will likely continue to expand.

Fedkiw, John.

1964. Forest industry capacity, production, and available log supplies in the Douglas-fir subregion. U. S. Forest Serv. Res. Paper PNW-11, 63 pp., illus.

Relations of capacity, production, and available log supplies are described in the lumber, plywood, and pulp industries of western Oregon and western Washington. Analysis is made of trends, outlook, and prospective problems of log supply and plant adjustment. Prospectively available log supplies are indicated by allowable-cut plans of public forestry agencies and by projections of available log supplies from private timberlands.

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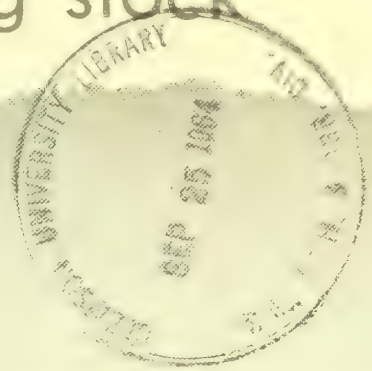
# ECONOMIC CONSIDERATIONS in management of Douglas-fir growing stock




- - - A CASE STUDY

by Norman P. Worthington and John Fedkiw

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE - FOREST SERVICE

U.S. FOREST SERVICE
RESEARCH PAPER PNW 12
1964

# SUMMARY

Thirteen years of commercial thinning beginning in 45- to 55-year-old Douglas-fir in central western Washington have demonstrated the silvicultural practicality and economic superiority of thinning over no thinning. Economic analysis indicates management with thinnings increased total net income after taxes by 3.6 percent. The increase is chiefly attributable to salvage of mortality through light, frequent thinnings. The increase in total net income probably would have been greater had the initial thinning been delayed 3 to 5 years, if poles and piling had been selected and sold separately, and if grade improvement on the better trees arising from redistribution of growth had been quantified.

Large and increasing capital investment in aging residual stands raises questions concerning economic efficiency of growing-stock capital and best time for its disinvestment and establishment of a new stand. The younger stands, now 55 years old, have a current volume growth percent of 4.0 and a value growth percent at least 1 percent greater due to increasing tree size and quality and to expected increases in young-growth stumpage prices. The problem is largely with the older stand, which is now 70 years old. Management of this older stand was examined under four alternatives: immediate disinvestment and regeneration; continuation of present light thinnings for 20 years; somewhat heavier thinning in the next 20 years; disinvestment 20 years hence without further thinning. Criterion for the management decision was attainment of a 3.5-percent after-tax return in the next 20 years. If the landowner's ordinary income tax rate is 50 percent, 3.5 percent after tax is equivalent to 7 percent before taxes.

Analysis showed that continued light thinning is the economically superior alternative, promising a 5.0-percent earning rate under a gradual 50-percent stumpage price increase, or a 3.0-percent rate at a constant stumpage price level. Thus, under the 3.5 criterion, the 70-year-old stand is financially mature and ready for regeneration unless stumpage prices increase. Analysis of the unthinned check areas indicates an earning rate substantially below the 3.5-percent rate and hence attainment of economic maturity prior to 1961.

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# ECONOMIC CONSIDERATIONS in management of Douglas-fir growing stock--

## A CASE STUDY

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# INTRODUCTION

Research in the management of young Douglas-fir has been conducted on the McCleary Experimental Forest[1] in western Washington since 1949.

To date, this research has been directed primarily toward increasing the productivity of young-growth stands through periodic commercial thinnings and toward determining whether such thinning operations can be profitable.

Experience has demonstrated the economic and silvicultural practicality of commercial thinning operations in Douglas-fir from 45 to 70 years old. On the other hand, the aging of the residual stands and their large capital investment have raised questions concerning the earning rate of the growing-stock capital and the optimum time or circumstances for harvesting the present stand and establishing a new one.

This paper describes 13 years of commercial thinning at McCleary and explores selected management alternatives for the present stand, now 55 to 70 years old and averaging 47,000 board feet per acre. Answers are sought for two specific questions:

1. Has commercial thinning from 1949 to 1961 been financially superior to holding the growing stock without thinnings? If so, by how much?

2. What is the best financial alternative for McCleary stands in the next 20 years: clear cutting and regenerating now; holding the growing stock without thinning to 1981; continuing a regime of light to medium thinnings?

Many timberland owners in the Douglas-fir region have young-growth stands similar to those described in this case history. Perhaps the method offered here for examining management alternatives can be adapted by landowners to their own situations in planning the management of their young-growth Douglas-fir stands.

[1] Maintained by the U. S. Forest Service in cooperation with the Simpson Timber Co.

# Description of the Forest

The forest consists of 340 acres of gentle-to-medium slopes in an elevation range from 300 to 600 feet. The soil is chiefly Olympic loam. The forest is largely Douglas-fir that originated after cutting in the western portion and after burning in the eastern portion. Two 1961 age classes have resulted: 55 years on the logged area and 70 years on the burned. Taken as a whole, the forest is well stocked.

Site index averages 180 feet (high site II) in the older stand and 170 feet (medium site II) in the younger. Mixtures of cedar, hemlock, and alder are common in the 55-year-old stand. Alder is dominant in the north quarter along the principal drainage. A June 1948 inventory[2] showed 2,147,000 cubic feet, or 9,423,440 board feet (Scribner rule), for all species (table 1). Douglas-fir, the predominant species, accounted for 68 percent of the cubic volume; alder, for 16 percent; and other species, for 16 percent.

Table 1.—Timber inventory, McCleary Experimental Forest, June 1948

| Species | Volume | | | |
|---|---|---|---|---|
| | Cubic[1] | | International 1/4-inch kerf[2] | Scribner rule[3] |
| | Cu. ft. | Percent | Bd. ft. | Bd. ft. |
| Douglas-fir | 1,468,256 | 68 | 9,492,460 | 7,032,900 |
| Cedar | 189,890 | 9 | 800,020 | 522,240 |
| Hemlock and spruce | 123,080 | 6 | 788,460 | 647,360 |
| Alder | 338,708 | 16 | 1,240,184 | 1,127,440 |
| Miscellaneous hardwoods | 27,200 | 1 | 102,850 | 93,500 |
| Total | 2,147,134 | 100 | 12,423,974 | 9,423,440 |
| Per acre | 6,315 | -- | 36,541 | 27,716 |

[1] Cubic-foot volume is for trees 6 inches d.b.h. and larger to a 4-inch top.

[2] All conifers 8 inches d.b.h. and larger to a minimum top diameter of 6 inches; alder and miscellnaeous hardwoods, 12 inches d.b.h. and larger to a minimum top diameter of 8 inches.

[3] All conifers 10 inches d.b.h. and larger to a minimum top diameter of 8 inches; all alder and miscellaneous hardwoods 12 inches d.b.h. and larger to a minimum top diameter of 8 inches.

[2] Data are from 170 concentric 1/10- and 1/5-acre plots spaced 264 feet apart in rows 330 feet apart. Trees 5.1 to 15.0 inches d.b.h. were tallied on the smaller area, and all trees over 15.0 inches were counted on the larger. On 25 percent of the plots, each tree was tagged and measured to the nearest one-tenth inch; on the remainder, measurement was by 2-inch classes, and individual tree identity was not preserved.

# The Management Practiced

In 1949, a policy decision was made to hold all stands for a decade or more. Variation in management was not proposed because stands were uniformly well stocked and fairly well along in age. Accordingly, light thinning, involving little or no risk of loss to the residual stand, was chosen as the appropriate management practice for the next decade or so.

To facilitate study of commercial thinning operations and the impact of such thinning on the development of the residual stands, the coniferous portion of the forest was divided into two blocks (fig. 1) constituting fairly distinct types and conditions. In each block, a check area was held undisturbed to compare with the development of the residual stand following commercial thinning:

| Type description | Block | Thinning area | Check area |
|---|---|---|---|
| | | — — Acres — — | |
| Mixed conifer and alder age 56 in 1961 | A | 85 | 15 |
| Even-aged Douglas-fir, age 69 in 1961 | B | 115 | 30 |
| Total acres | | 200 | 45 |

Blocks A and B, chiefly Douglas-fir, were each divided into five compartments to systematize annual thinning operations. A compartment of about 40 acres in each block was thinned annually so that each block was covered every 5 years. The 1961 harvest completed 13 years of commercial thinning.

No cuttings have been made on the remaining 95 acres of the forest, where the stand is predominantly alder in mixture with conifers.

## Thinning Yields

Thinnings produced 2,286,945 board feet, Scribner rule (table 2). The greater annual yields in the first thinning cycle, 1949-53, arose largely from the heavier volumes harvested on road rights-of-way and from a heavier initial thinning. During the second and third thinning cycles, annual thinning yields have varied between 114,000 and 144,000 board feet, averaging about 75 percent of the annual increment.

Table 2.—Thinning yields, 1949-61, McCleary Experimental Forest

| Year | Douglas-fir[1] | Alder | Total |
|---|---|---|---|
| | — — — Board feet, Scribner rule — — — | | |
| 1949 | 199,831 | 0 | 199,831 |
| 1950 | 422,271 | 6,251 | 428,522 |
| 1951 | 257,000 | 15,000 | 272,000 |
| 1952 | 220,000 | 22,000 | 242,000 |
| 1953 | 141,791 | 19,400 | 161,191 |
| 1954 | 95,726 | 22,385 | 118,111 |
| 1955 | 102,000 | 11,570 | 113,570 |
| 1956 | 106,000 | 14,000 | 120,000 |
| 1957 | 115,000 | 6,000 | 121,000 |
| 1958 | 117,000 | 27,000 | 144,000 |
| 1959 | 101,730 | 20,500 | 122,230 |
| 1960 | 111,240 | 16,600 | 127,840 |
| 1961 | 106,650 | 10,000 | 116,650 |
| Total | 2,096,239 | 190,706 | [2]2,286,945 |

[1] Less than 5 percent hemlock and cedar.
[2] Includes 210,000 board feet cut from rights-of-way, 9.2 percent of total cut.

Trees that were dying, misshapen, or broken predominated in the first thinnings. Rough, limby dominants, whose removal was expected to release trees of better form and quality, were taken later. In addition, other trees were cut to improve spacing where the residual trees were judged capable of good increment response.

## Road Development and Maintenance

Roads were constructed to Forest Service single-lane standards by the operator who purchased the stumpage. To date, 1.95 miles (80 percent surfaced) have been completed. To adequately serve the 340-acre forest, the system should be extended to 2.4 miles, which would be an intensity of 142 acres per mile or 4.32 miles per section. Then, no point would be over 1,000 feet from a road.

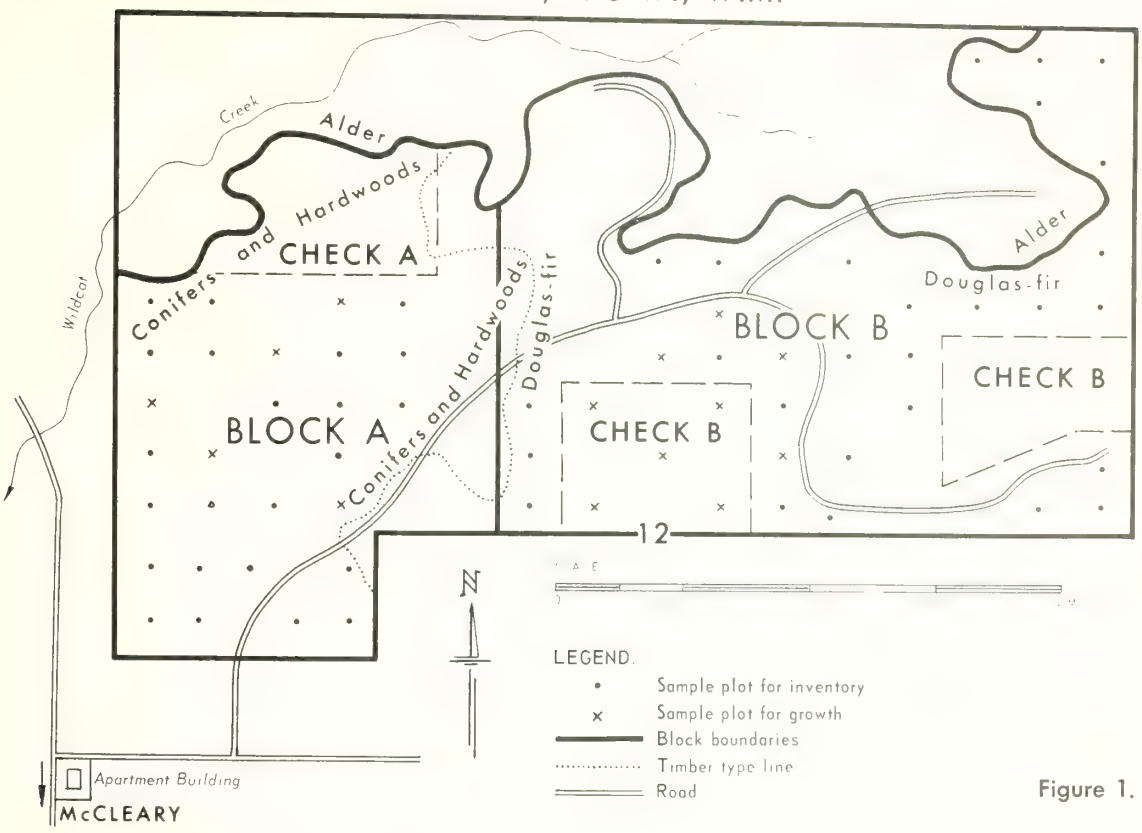


Figure 1.

Road cost, including location and engineering, was $6,336 per mile, and annual maintenance costs have averaged $35 per mile since the 1.95 miles of road were completed in 1952 (table 3). The total road investment was $12,354.75, amounting to $1.06 per thousand board feet, Scribner rule, when prorated over past thinnings and the 1961 inventory volume for blocks A and B (table 6).

Table 3.—Road expenditures and stumpage revenues, McCleary Experimental Forest, 1949-61

| Year | Road construction[1] | | Annual road maintenance | Stumpage [illegible] | |
|---|---|---|---|---|---|
| | Annual | Cumulative | | Annual | Cumulative |
| | Dollars | | | | |
| 1949 | 559.27 | 559.27 | 0 | 1,198.99 | 1,198.99 |
| 1950 | 4,323.60 | 4,882.87 | 0 | 3,063.66 | 4,262.65 |
| 1951 | 3,388.36 | 8,271.23 | 0 | 3,306.00 | 7,568.65 |
| 1952 | 2,640.81 | 10,912.04 | 50.00 | 3,234.00 | 10,802.65 |
| 1953 | 763.51 | 11,675.55 | 0 | 1,893.00 | 12,695.65 |
| 1954 | 216.11 | 11,891.66 | 0 | 1,272.04 | 13,967.69 |
| 1955 | 237.48 | 12,129.14 | 0 | 1,550.50 | 15,518.19 |
| 1956 | 225.61 | 12,354.75 | 187.00 | 1,727.00 | 17,245.19 |
| 1957 | 0 | 12,354.75 | 267.00 | 1,617.00 | 18,862.19 |
| 1958 | 0 | 12,354.75 | 100.00 | 1,686.00 | 20,548.19 |
| 1959 | 0 | 12,354.75 | 20.00 | 1,628.45 | 22,176.64 |
| 1960 | 0 | 12,354.75 | 0 | 1,584.74 | 23,761.38 |
| 1961 | 0 | 12,354.75 | 57.00 | 1,644.75 | 25,406.13 |

[1] Includes $1,000-per-mile allowance for road location and engineering or a total of $1,950 allocated in proportion to annual expenditure.
[2] Before income taxes. Maximum reduction of stumpage revenues would be 25 percent. The actual income tax impact for any individual case would be somewhat lower, depending upon depletion rate and the income tax bracket of the owner.

Net stumpage revenue ($7,127, col. 11, table 7), derived from clearing rights-of-way and from thinnings during the first 5-year cycle, was sufficient to fund 61 percent of the road investment cost in that period (tables 3 and 7). By the end of the second cycle, net revenue was sufficient to fund 91 percent of the total road investment. The road investment actually is not an extra cost but an advance outlay that would otherwise have to be made when the stand was clear cut. In this light, management of young growth in the first two thinning cycles amounts to a conversion of timber capital into road capital. The latter is more productive since it makes possible an increase in income and timber yield through salvage of accumulated mortality and capture of additional mortality that would occur before final harvest. In addition, advance roading can reduce risks and costs of protection and administration. Increased yields plus reduced costs and risks are a net gain over income that would have been produced had the forest been left unroaded until time of final harvest.

## Markets and Prices

For the first 10 years, annual stumpage sales were made to a nearby small mill operator, who either logged the timber with his own crew or subcontracted the work. The operator sold some of the better timber as peeler logs. The bulk, however, was processed as lumber or cants through his sawmill and sold locally or to an Olympia concentration yard. In 1960 and 1961, stumpage was sold to a logger who, in turn, sold his logs to other mills.

All stumpage sales were for a lump sum. Sale volume was determined from an individual tree count (by d.b.h.) made when the timber was marked.

Conifers down to 9.0 inches d.b.h. were marked for cutting and utilized to a 6- to 7-inch minimum top diameter, since the only market outlet was for saw logs and veneer logs. Alder, to a 6-inch minimum top, usually was sold as pulp logs.

The annual stumpage rates realized from Douglas-fir thinnings have ranged from $6 per thousand board feet in 1949 to a maximum of $15.50 in 1956 (fig. 2). The alder price range has been narrower—from $4 to $7.50 per thousand board feet. Total stumpage receipts from 1949 through 1961 were $25,406.13 for 2,286,945 board feet of all species (tables 2 and 3).

## Logging Costs

Records of logging costs for two successive 3-year periods, 1950-52 and 1953-55, are summarized in table 4. Average total costs per thousand board feet between the two periods declined 5 percent to $25.97. Labor efficiency improved 21 percent in the same period, but this improvement was offset in part by a 42-cent increase in the average hourly wage.

Table 4.—Average thinning costs and production efficiency for two 3-year periods, McCleary Experimental Forest[1]

| Item | Man-hours per thousand board feet | | Cost per thousand board feet | |
|---|---|---|---|---|
| | 1950-52 | 1953-55 | 1950-52 | 1953-55 |
| Felling and bucking | 1.66 | 1.46 | $4.57 | $4.34 |
| Skidding | 1.88 | 1.82 | 6.64 | 8.21 |
| Loading | 1.03 | .83 | 3.97 | 2.91 |
| Trucking | .94 | .86 | 4.35 | 2.97 |
| Moving and road maint. | 1.02 | .29 | 1.77 | 1.18 |
| Administration | .81 | .55 | 1.29 | 1.53 |
| Taxes | — | — | 1.56 | 1.83 |
| Subtotal | 7.34 | 5.81 | 24.15 | 22.97 |
| Profit allowance | -- | -- | 3.00 | 3.00 |
| Total | 7.34 | 5.81 | 27.15 | 25.97 |

[1] Adapted from table 1 of: Worthington, Norman P. Some economic considerations in thinning Douglas-fir. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 137, 7 pp. 1957.

Currently, average total costs per thousand board feet are from 5 to 10 percent higher than in 1950-55. Labor efficiency is further improved, but average hourly wages have increased more.

In the 1950-52 period, average cut per acre was 5,603 board feet, including right-of-way

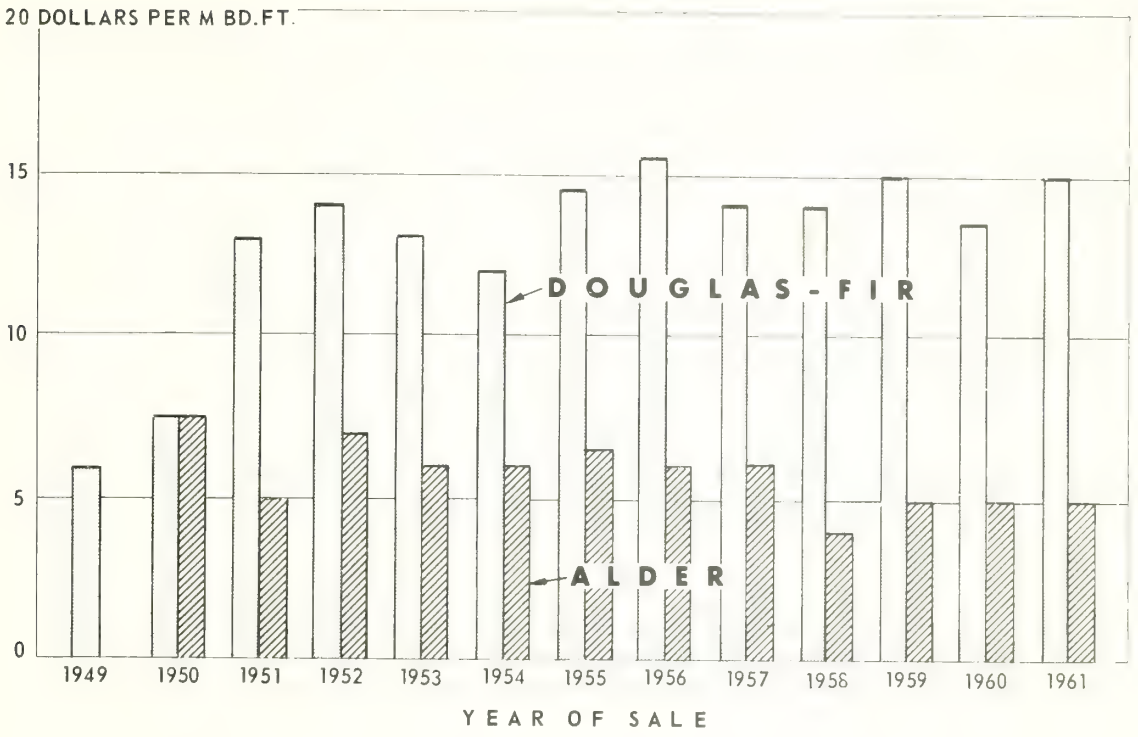


Figure 2.—Annual stumpage prices, McCleary Experimental Forest, 1949-62.

timber. The total harvest was 814,000 board feet, and average d.b.h. of cut trees was 16.8 inches. The average cut per acre in the second period was 3,098 board feet, mostly from second thinnings. The total harvest was 416,000 board feet, and average d.b.h. for cut trees was 15.6 inches.

The great improvement in labor efficiency in the second period is attributed largely to two basic changes: (1) reduction of logging crew to two or three men (from a former five to nine men), accompanied by less specialization of labor, better coordination among the crew, and less loss of labor output during breakdowns; (2) shift from "hot" logging to decking along roadside and loading with a mobile loader, thus reducing skidding time and eliminating waiting time due to intermittent shortages of logs to load out.

## Direct Management Expenses

The principal expenses in managing second-growth timber are costs of marking, selling, and supervising the thinning operation. These are in addition to costs of road location and engineering, which are part of the road investment.

The cost of marking 184,000 board feet prepared for sale in 1962 was estimated at $1.05 per thousand. This is based on 4 man-days of field work, 200 miles of auto transportation, $12.25 for materials and equipment, $18 for office work, and $26 for payroll taxes and other burden. The costs of selling and supervision, $1.20 per thousand board feet, include 6 man-days, 300 miles of auto transportation, and $40 for payroll taxes and other burden. Thus, the total direct management expense is estimated

at $2.25 per thousand board feet, log scale, Scribner rule. This cost is based on use of resident personnel. Similar work done by consultants, excluding allowance for profit, would cost about 20 percent more, or $2.70, due to greater travel and associated expense.

## Fixed Ownership Expenses

Fixed expenses are those which must be incurred and paid whether young-growth timber is managed for thinnings or held for clear cutting. These include protection, ad valorem taxes, and administration of the property. Table 5 shows the schedule of costs incurred for these purposes from 1949 to 1961. It also includes yield tax payments, which are a direct expense of thinning since they are paid only when timber is harvested.

thinnings was financially superior to holding the growing stock without thinning for the period 1949-61. The economic advantage of the thinning system is estimated at $5,860 for blocks A and B in 1961, or about $1.84 per acre per year.

In this analysis, the owner is assumed to be a private landowner who builds the roads on his property, sells stumpage to a logger or contractor, and is in the 50-percent income tax bracket. This assumption is presumed to be consistent with ownership of a half section or more of second-growth Douglas-fir, which has a current liquidation value approaching $1,000 per acre.

At the end of 1961, the net cumulative cash exceeded road investment requirements by $1,462. Because the return from the best alternative investment of funds used to build roads is assumed to have been 3.5 percent com-

Table 5.—Fixed annual expenses of ownership, including yield taxes, McCleary Experimental Forest, 1949-61

| Year | Fire patrol[1] | | Ad valorem taxes paid[2] | Yield tax on harvested timber | | Estimated annual expense of administration |
|---|---|---|---|---|---|---|
| | Payments | Rate per acre | | Payments | Tax rate | |
| | Dollars | Cents | Dollars | Dollars | Percent | Dollars |
| 1949 | 20.80 | 6.5 | 39.11 | 32.40 | 3.0 | 150 |
| 1950 | 20.80 | 6.5 | 31.71 | 115.50 | 4.0 | 150 |
| 1951 | 25.60 | 8.0 | 39.04 | 156.00 | 5.0 | 150 |
| 1952 | 28.80 | 9.0 | 31.88 | 227.00 | 7.0 | 150 |
| 1953 | 28.80 | 9.0 | 47.94 | 84.48 | 8.0 | 150 |
| 1954 | 28.80 | 9.0 | 34.78 | 58.21 | 10.0 | 150 |
| 1955 | 28.80 | 9.0 | 18.82 | 96.03 | 9.0 | 150 |
| 1956 | 28.80 | 9.0 | 16.56 | 180.00 | 10.0 | 150 |
| 1957 | 28.80 | 9.0 | 14.83 | 139.70 | 11.0 | 150 |
| 1958 | 28.80 | 9.0 | 20.52 | 78.91 | 12.0 | 150 |
| 1959 | 32.00 | 10.0 | 18.80 | 165.75 | 12.5 | 150 |
| 1960 | 33.60 | 10.5 | 17.72 | 150.71 | 12.5 | 150 |
| 1961 | 32.00 | 10.0 | 15.56 | 180.51 | 12.5 | 150 |
| Total | 366.40 | -- | 347.27 | 1,665.20 | -- | 1,950 |

[1] Paid to Washington Forest Fire Association whose rates are approximately $0.01 more than State fire patrol charge.
[2] Two hundred acres classified under State Reforestation Act in 1946; 140 acres classified in 1955. Year-to-year variation is largely due to changes in the annual tax rate.

## Analysis of Financial Experience

The financial experience in thinning blocks A and B has been analyzed (tables 6 and 7) and later compared with the expected experience had these stands not been thinned. The comparison shows that management with light

pounded after taxes on the earnings,[3] the gain in cash at the end of 1961 ($160) is lower. The road investment, however, is completely amortized, and the road is adequate for final harvest purposes.

[3] This is equivalent to a 7-percent rate of return before application of the 50-percent personal income tax assumed for this case.

## Table 6.—Calculation of net stumpage revenue after tax on capital gain, blocks A and B, McCleary Experimental Forest, 1949-61

| Year | Thinning yields | Inventory | | Stumpage revenue | Timber depletion[1] | Capital gain[2] | Road depreciation[3] | Direct selling expense[4] | Taxable gain[5] | Tax on capital gain[6] | Net revenue after tax on capital gain |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Thinned | Unthinned | | | | | | | | |
| | M Bd. ft. | — — M Bd. ft. — — | | — — —

Complete financial comparison of the alternative systems of management required evaluation of the growing stock as of the end of 1961. For the thinned stand, which had an average d.b.h. of 19.1 inches, Douglas-fir was valued at $27.05 per thousand board feet[4]. Other conifers were valued at 65 percent of this, or $17.85 per thousand, and alder at $4.75 per thousand, the average experience of the previous 5 years. The weighted average price of the thinned residual stand was, accordingly, $25.72 per thousand board feet.

Total yields at the end of 1961 were as follows:

| | Thousand board feet | Percent |
|---|---|---|
| Thinned stand: | | |
| Thinnings (1949-61) | 2,287 | 19.5 |
| Residual stand (1961): | | |
| Douglas-fir | 8,162 | 69.7 |
| Other conifers | 1,223 | 10.4 |
| Alder | 42 | .4 |
| Total residual stand | 9,427 | 80.5 |
| Total yield | 11,714 | 100.0 |
| Unthinned stand: | | |
| Douglas-fir | 9,535 | 86.7 |
| Other conifers | 1,243 | 11.3 |
| Alder | 220 | 2.0 |
| Total yield | 10,998 | 100.0 |

Average value per thousand board feet for the unthinned stand was derived partly from the sale experience on thinnings and partly from valuation of the thinned stand. In the thinned stand, 19.5 percent of the total yield, or 2,287,000 board feet, was harvested as thinnings. Average price received for thinnings over the 5 years, 1956-61, was $12.92 compared with $11.11 for all thinnings. For valuation of the unthinned stand, $12.92 was applied to 2,287,000 board feet, i.e., to that amount taken as thinnings from the thinned stand, and the balance was valued at $25.72 per thousand the same as for the residual thinned stand. This places an average value of $23.06 per thousand on the unthinned stand compared with an average of $22.87 per thousand for the total yield from the thinned stand. With these values, the appraisal of the after-tax value of the inventory volume for alternative management assumptions is as follows:

| | Thinned | Unthinned |
|---|---|---|
| 1961 inventory ----------M board feet | 9,427 | 10,998 |
| Value per thousand board feet --Dollars | 25.72 | 23.06 |
| Total stumpage value --------Dollars | 242,462 | 253,595 |
| Less residual depletion ------Dollars | 5,600 | 7,701 |
| Capital gain ----------Dollars | 236,862 | 245,894 |
| Less residual road depreciation or current road cost --------Dollars | 9,931 | 12,355 |
| Less direct selling expense[1] ---Dollars | 3,771 | 4,399 |
| Taxable gain ----------Dollars | 223,160 | 229,140 |
| Less tax on gain ----------Dollars | 55,790 | 57,285 |
| Net stumpage revenue after tax on gain ----------Dollars | 167,370 | 171,855 |
| Less yield tax[2] ----------Dollars | 15,154 | 15,850 |
| Less fixed annual expense[3] 1949-61 ----------Dollars | 0 | 1,659 |
| Net income from timber property Dollars | 152,216 | 154,346 |
| Plus depletion ----------Dollars | 5,600 | 7,701 |
| Plus road residual depreciation[4] ----------Dollars | 9,931 | 0 |
| Plus cumulative net cash flow from thinnings ----------Dollars | 160 | 0 |
| | 167,907 | 162,047 |
| Incremental income after taxes available under thinning system ------Dollars | 5,860 | |

[1] Calculated at $0.40 per thousand for final clear cut
[2] Calculated at 12-1/2 percent of total stumpage value and reduced 60 percent to put it on an after-tax basis
[3] Includes an after-tax interest cost of 3.5 percent per year. For the thinned stand, fixed annual expense was subtracted in calculating net cash flow from thinnings (table 7).
[4] Since the calculation of cumulative net cash flow from thinnings provides for full amortization of the roads, depreciation recovered at time of final harvest becomes net income after taxes.

The foregoing appraisal indicates $5,860, or 3.6 percent, more net cash flow after taxes for blocks A and B under a system of advance roading and thinning than could have been realized had the blocks been left unthinned. This increase in net income amounts to about $1.84 per acre per year. In this appraisal, it comes primarily from the extra yields realized from the capture of mortality through regular thinning. It does not reflect any relative improvement in grade recovery in the thinned stand through redistribution of growth onto higher value trees other than that associated with diameter growth alone. The lower stumpage prices received for the earlier thinnings also lends conservatism to this appraisal of thinning in young-growth Douglas-fir.

In conclusion, holding the stands in blocks A and B through 1961 and thinning lightly with emphasis on leaving higher grade trees was better financial management than holding the stands without thinning. A 3- to 5-year delay in initiation of thinnings; more diversified marketing of thinnings for special products—particularly poles and piling; and quantification of grade improvement attributable to redistribution of growth to better trees, probably would have shown a greater net benefit than that disclosed by the foregoing analysis. This is the answer to the first question posed in this case study.

[4] Derived from the calculated stumpage value by d.b.h. in Schedule A of the Appendix.

# The Current Management Planning Situation

The situation on the McCleary Experimental Forest has changed considerably since the decision to thin was made in 1949. Experience has shown that periodic thinning, which captures past and expected mortality, was financially superior to not thinning in stands between 43 and 56 years old held for an additional 13 years. The level and quality of growth stock in both stand A and stand B[5] have been substantially improved. With roads established, periodic thinning operations can continue to capture the gross growth in both stands, but is it financially practical to do so?

Stand A is now 56 years old; stand B is 69 years old. What would be the best financial alternative for these stands in the next 20 years? clear cutting and regenerating now? holding the growing stock without thinning to 1981? continuing with light to medium thinnings?

## Growth Performance of Stand A

Stand A has an average basal area of 161 square feet per acre. Average number of trees per acre is 113 with an average d.b.h. of 16.2 inches, including both conifers and alder.

[5] Hereinafter, stands A and B refer to the thinned portions of blocks A and B.

Board-foot annual growth percent of the dominant and codominant Douglas-fir trees of the residual stand, as determined from tree remeasurement data on five permanent sample plots, was 6.2 percent for the period 1948-61 (table 8). These tree volumes constitute 50 percent of the current (1961) plot inventory of 28,034 board feet per acre. For the period 1948-61, average stocking for all of stand A was 24,680 board feet per acre with a net annual growth of 1,067 board feet per acre, indicating an average annual stand growth rate of 4.3 percent over the past 13 years. Due to the higher level of growing stock, current growth per acre is somewhat more than 1,067 board feet, and growth rate is approaching 4.0 percent.

In the next decade, volume growth percent will continue to decline due to further increases in growing stock, decreases in board-foot growth per acre, and less ingrowth from trees below 10 inches d.b.h. Value growth percent, however, is expected to be from 1 to 2 percent higher than volume growth percent. At the same time, stocking will be adequate to capture close to full gross growth potential of the site. Accordingly, it is judged that with periodic light thinnings stand A will continue to earn somewhat more than 4-percent return on investment during the next decade and perhaps

Table 8.—Douglas-fir tree size and volume growth percent for stand A, McCleary Experimental Forest

| Plot No. | Number of trees[1] | D.b.h. of average tree | | Volume of average tree | | Volume growth percent |
|---|---|---|---|---|---|---|
| | | 1948 | 1961 | 1948 | 1961 | |
| | | — — Inches — — | | — — Board feet — — | | |
| 126 | 5 | 14.2 | 18.9 | 150 | 385 | 7.0 |
| 130 | 6 | 19.7 | 24.2 | 354 | 675 | 4.7 |
| 137 | 9 | 12.1 | 16.1 | 93 | 266 | 7.8 |
| 149 | 8 | 16.4 | 20.9 | 218 | 483 | 5.8 |
| 158 | 5 | 12.2 | 16.8 | 95 | 294 | 8.4 |
| Average | -- | 15.1 | 19.5 | 180 | 415 | 6.2 |

[1] Sample from a total of 101 trees present on these five 0.2-acre plots. Sample trees are all surviving Douglas-fir 10 inches d.b.h. or larger in 1948 and are mostly dominants and codominants constituting 50 percent of 1961 sawtimber volume for all species.

longer. No further refinement in the economic evaluation of stand A is considered necessary to justify holding it.

The case of stand B, however, is more critical, and a more careful evaluation of its economic outlook is necessary.

## Growth Performance of Stand B

The average basal area of stand B for both conifers and alder is 198 square feet per acre. With 82 trees per acre, the average d.b.h. is 21.0 inches.

During the 10-year period following the first thinning, gross increment, determined from five permanent sample plots in an average compartment, was 12,721 board feet per acre, or 1,272 board feet annually. This includes 1,099 board feet of mortality harvested in the 1955 and 1960 thinnings. Total thinning volume (from three thinnings and salvaged mortality) was 19,216 board feet. Growing stock has increased 4,122 board feet since the first thinning, or 32 percent of the gross increment. Table 9 details the performance of stand B between 1950 and 1960 by 5-year periods.

Comparison with permanent sample plot data from the unthinned portion of block B indicates that thinning operations increased yields per acre by about 189 board feet annually (thinned gross increment of 1,272 board feet against unthinned net of 1,083 board feet). Table 10 gives the increment analysis for the unthinned stand for the 8-year period 1953-61.

Table 10.—Increment analysis of unthinned stands, block B, McCleary Experimental Forest, 1953-61[1]

| Year | Volume per acre | Increment per acre | | | Growth percent |
|---|---|---|---|---|---|
| | | Gross | Mortality | Net | |
| | Board feet, Scribner rule | | | | |
| 1953 | 61,409 | 10,895 | 2,235 | 8,660 | 1.7 |
| 1961 | 70,069 | | | | |
| Annual basis | -- | 1,362 | 279 | 1,083 | -- |

[1] Based on the following 0.2-acre plots: 68, 70, 79, 88, 90.

The 1960 board-foot growth percent of stand B is estimated at 2.7, somewhat less than that for the 5 years, 1955-60. For the 20-year period to 1981, the growth percent is expected to fall below 2.7 as growing stock accumulates and growth rate declines with age.

Growth percent for the unthinned check stand in block B is estimated to be 1.7, considerably lower than that for the thinned portion of block B.

Table 9.—Increment analysis of thinned stand, block B, McCleary Experimental Forest, 1950-60[1]

| Year of thinning | Volume per acre | | | Increment per acre | | | Growth percent |
|---|---|---|---|---|---|---|---|
| | Before thinning | Thinning removals | After thinning | Gross | Mortality | Net | |
| | Board feet, Scribner rule | | | | | | |
| 1950 | 55,128 | 10,617 | 44,511 | 5,883 | 679 | 5,204 | 2.5 |
| 1955 | 49,715 | 2,883 | 46,832 | 6,838 | 420 | 6,418 | 2.8 |
| 1960 | 53,250 | 4,617 | 48,633 | | | | |
| Total | -- | [2]19,216 | -- | 12,721 | [3]1,099 | 11,622 | -- |
| Annual basis | -- | -- | -- | 1,272 | 110 | 1,162 | -- |

[1] Based on the following 0.2-acre plots: 57, 59, 66, 77, 96.
[2] Includes 1,099 board feet of mortality salvaged.
[3] Salvaged in 1955 and 1960 thinnings.

# The Main Management Problem and Its Analysis

The main problem centers on stand B. In 1961, net volume per acre was 49,839 board feet, Scribner rule, including 1,067 board feet of alder. Net value was approaching $1,000 an acre, if not more.

Earning rate as a capital asset was below 3 percent insofar as can be ascertained from its volume growth percent. Rates of return available from riskless bank savings or government bonds and from investment opportunities in the private markets for capital were significantly greater than the volume growth percent of stand B. Since earnings from some of these alternative opportunities would be subject to a 50-percent personal income tax for the assumed ownership situation, the after-tax earning rates would range from somewhat less than 2 percent upwards to 5 percent.

It is true that the value growth percent of stand B may be somewhat greater than its volume growth percent due to continuing improvement in tree grade and size. But after 21.7 inches in d.b.h. is attained, the average for conifers in stand B, the favorable influence of grade and size improvement on value growth percent probably falls below 1 percent.

## Definition of Management Alternatives

To better determine whether stand B has reached financial maturity, the following practical alternatives are proposed for examination:

Plan A. Clear cut now, and reproduce.

Plan B. Hold without further thinning for 20 years; clear cut and reproduce about 1981.

Plan C. Thin heavily (7,500 board feet per acre) at 5-year intervals for 20 years; clear cut and reproduce about 1981.

Plan D. Thin lightly (4,000 board feet per acre) at 5-year intervals for 20 years; clear cut and reproduce about 1981.

## Basic Assumptions

PRICES

Two price assumptions are examined:

(a) Stumpage prices remain constant in terms of 1961 dollars.

(b) Stumpage prices for Douglas-fir increase linearly to $30 per thousand board feet for trees 16 inches in d.b.h. by the year 1981. Stumpage prices of other conifers remain at 65 percent of the stumpage price for Douglas-fir. Alder prices remain constant at $6 per thousand.

The increase in stumpage prices for conifers is assumed to be more likely than constant prices. It is expected that the price trend will not be perfectly linear. The increase to $30 for 16-inch Douglas-fir trees is viewed as a very likely price outlook for the latter part of the planning period, 1976-81, but not before that time.

PLANNING PERIOD

The planning period is taken as 20 years, but it is understood that the action can be altered as circumstances dictate at any time within the next 20 years should the decision favor plans B, C, or D now.

GRADE RECOVERY

The grade of growing stock is assumed to improve with increase in diameter. It is also assumed that improvements in grade will be recognized by the market in accordance with schedule A in the appendix.

STAND COMPOSITION

The ratio of Douglas-fir to other conifers remains constant. Alder of various ages and sizes remains as a scattered and "patchy" component of the stand to 1981.

THINNING REGIME

In practice, thinnings would be carried out on one-fifth of the area of stand B each year. For analytical purposes, income from thinnings is taken only at 5-year intervals, with the first thinning yields calculated for 1966.

GROWTH AND YIELD ESTIMATES

Estimates are the best available knowledge for the management of the lands involved. They are considered physically attainable and the most likely outcome for the individual plans being considered.

COSTS

Direct costs for marking, selling, and supervising thinning is calculated at $2.25 per thousand board feet.

Direct cost for selling and supervising the final clear cut is calculated at $0.40 per thousand board feet.

Road maintenance is calculated at $1 per thousand board feet (thinnings and final clear harvest) for all plans.

Regeneration cost is estimated at $50 per acre.

Undepreciated road investment in 1961 is $41 per acre.

Depletion base is $37 per acre in 1961.

Yield tax is calculated at 3 percent of stumpage revenue in 1949 and increased 1 percent per year thereafter until 1959 when the maximum rate of 12.5 percent was reached.

Annual costs of protection, general administration, and ad valorem taxes, estimated at $0.80 per acre, are assumed fixed at the same average amount per acre for all alternative plans.

## Method of Analysis and Decision Criteria

The first objective of the analysis is to compare plans B, C, and D with plan A to determine whether it might be profitable to hold and manage stand B for an additional 20 years. The criterion for holding is a 3.5-percent rate of return on the cash flow, after Federal income taxes, obtainable from harvesting and regenerating stand B now. It is understood that a 3.5-percent return so calculated is an average rate and would involve carrying some growing stock increasing in value at less as well as some increasing at more than 3.5 percent. This is considered practically tolerable where the average rate is 3.5 percent or greater.

If more than one plan meets the foregoing rate of return criterion, then a secondary evaluation would be necessary to determine which plan is best. In such an event, that plan would be best which carries the least amount of growing stock increasing at less than 3.5 percent. Theoretically, this would be the plan with the highest internal rate of return.

From the standpoint of the landowner, the 3.5-percent return after Federal income taxes is taken as his guiding rate of return on investment opportunities of comparable risk. For investments subject to the owner's 50-percent ordinary income tax rate, 3.5 percent after taxes is equivalent to 7 percent before taxes. Some optimistic investors may well expect a higher rate of return on their capital. More conservative investors may be satisfied with a lower return. Their decisions with regard to stand B would vary accordingly.

The rates of return for plans B, C, and D are solved with the following general equation:

$$CF_A \cdot R = \frac{CF_{T5}}{(1.0p)^5} + \frac{CF_{T10}}{(1.0p)^{10}} + \frac{CF_{T15}}{(1.0p)^{15}} + \frac{CF_{F20}}{(1.0p)^{20}} \cdot R$$

$CF_A$ stands for cash flow from plan A. It is the net cash the owner would have from the sale of his timber after all operating costs, yield taxes, and Federal income taxes were paid. $CF_A$, then, is the capital that would be available for reinvestment under plan A, but which would remain invested in tember if plan B, C, or D is followed.

R is the regeneration cost.

$CF_T$ and $CF_F$ are the cash flow from thinnings and the final clear cut, respectively. For plans C and D, where several different time periods are involved, interest rate (p) must be solved by trial and error, beginning with an

estimated p and working by successive approximations until that p is found which brings about equality in the equation.

The numerical subscripts and exponents are the number of years elapsed from 1961.

## Production Schedules and Financial Analyses for Alternative Plans

Production schedules are based on volume, growth, mortality, and tree count data taken from permanent sample plots in stand B. The expected production schedules for each plan and the cash flow analysis and internal rates of return for each plan are presented in tables 11 and 12.

Table 11.—Per-acre production schedules under plans A, B, C, and D for stand B

| Plan | Year | Stand before thinning | | Thinning harvest | | | Residual stand | | | Number of Conifers |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Conifers | Alder | Conifers | D. b. h. | Alder | Conifers | D. b. h. | Alder | |
| | | Bd. ft. | Bd. ft. | Bd. ft. | Inches | Bd. ft. | Bd. ft. | Inches | Bd. ft. | |
| A | 1961 | -- | -- | -- | -- | | 48,772 | 21.7 | 1,067 | 74.0 |
| B | 1961 | -- | -- | -- | -- | -- | 48,772 | 21.7 | 1,067 | 74.0 |
| | 1966 | -- | -- | -- | -- | | 54,177 | 22.9 | 1,142 | 71.9 |
| | 1971 | -- | -- | -- | -- | -- | 59,582 | 24.1 | 1,202 | 70.9 |
| | 1976 | -- | -- | -- | -- | -- | 64,387 | 25.2 | 1,262 | 68.0 |
| | 1981 | -- | -- | -- | -- | -- | [1]70,192 | 26.3 | 1,312 | 66.1 |
| C | 1961 | -- | -- | -- | -- | | 48,772 | 21.7 | 1,067 | 74.0 |
| | 1966 | 54,727 | 1,142 | 7,500 | 18.0 | 327 | 47,227 | 24.0 | 815 | 56.1 |
| | 1971 | 52,771 | 865 | 7,500 | 20.0 | 150 | 45,271 | 26.7 | 715 | 42.2 |
| | 1976 | 50,174 | 785 | 7,500 | 22.0 | 170 | 42,674 | 29.9 | 615 | 31.2 |
| | 1981 | -- | -- | -- | -- | -- | 47,151 | 31.4 | 665 | 31.2 |
| D | 1961 | -- | -- | -- | -- | -- | 48,772 | 21.7 | 1,067 | 74.0 |
| | 1966 | 54,727 | 1,142 | 4,000 | 17.0 | 327 | 50,727 | 23.6 | 815 | 63.1 |
| | 1971 | 56,682 | 865 | 4,000 | 18.0 | 150 | 52,682 | 25.6 | 715 | 53.6 |
| | 1976 | 58,387 | 785 | 4,000 | 19.0 | 170 | 54,387 | 28.2 | 615 | 45.1 |
| | 1981 | -- | -- | -- | -- | -- | 60,092 | 29.5 | 665 | 45.1 |

[1] Includes 1,000 board feet of salvage.

## Table 12.—Financial analysis of alternative plans for stand B

| Plan | Year | Stumpage revenue | Depletion[1] | Road depreciation[2] | Direct selling expenses[3] | Taxable gain[4] | Net stumpage revenue after tax on gain[5] | Property expenses: Road maintenance[6] | Property expenses: Yield tax[7] | Property expenses: Total after-tax cost[8] | Net income from timber property[9] | Cash flow[10] | Regeneration cost | Cumulative net cash flow in 1981: Without interest | Cumulative net cash flow in 1981: With interest | Internal rate of return after taxes[11] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Dollars per acre | | | | | | | | Percent |
| **CONSTANT STUMPAGE PRICE** | | | | | | | | | | | | | | | | |
| A | 1961 | 1,553 | 37 | 41 | 20 | 1,455 | 1,091 | 50 | 194 | 122 | 969 | 1,047 | 50 | 997 | 1,984 | 4-3.5[12] |
| B | 1981 | 2,596 | 37 | 41 | 29 | 2,489 | 1,867 | 72 | 325 | 198 | 1,669 | 1,747 | 50 | 1,697 | 1,697 | 2.7 |
| C | 1966 | 188 | 4 | 5 | 18 | 161 | 121 | 8 | 24 | 16 | 105 | 114 | | 114 | 114 | |
| | 1971 | 212 | 4 | 4 | 17 | 187 | 140 | 8 | 26 | 17 | 123 | 131 | | 245 | 266 | |
| | 1976 | 244 | 4 | 4 | 17 | 219 | 164 | 8 | 30 | 19 | 145 | 153 | | 398 | 469 | |
| | 1981 | 1,900 | 25 | 25 | 19 | 1,828 | 1,371 | 48 | 238 | 143 | 1,228 | 1,281 | 50 | 1,629 | 1,786 | 2.9 |
| D | 1966 | 93 | 2 | 2 | 10 | 79 | 59 | 4 | 12 | 8 | 51 | 55 | | 55 | 55 | |
| | 1971 | 100 | 2 | 2 | 9 | 87 | 65 | 4 | 12 | 8 | 57 | 61 | | 116 | 126 | |
| | 1976 | 107 | 2 | 2 | 9 | 94 | 70 | 4 | 13 | 8 | 62 | 66 | | 182 | 216 | |
| | 1981 | 2,398 | 31 | 35 | 24 | 2,308 | 1,731 | 61 | 300 | 180 | 1,551 | 1,617 | 50 | 1,749 | 1,824 | 3.0 |
| **RISING STUMPAGE PRICE** | | | | | | | | | | | | | | | | |
| B | 1981 | 3,686 | 37 | 41 | 29 | 3,579 | 2,684 | 72 | 461 | 266 | 2,418 | 2,496 | 50 | 2,446 | 2,446 | 4.6 |
| C | 1966 | 207 | 4 | 5 | 18 | 180 | 135 | 8 | 26 | 17 | 118 | 127 | | 127 | 127 | |
| | 1971 | 257 | 4 | 4 | 17 | 232 | 174 | 8 | 32 | 20 | 154 | 162 | | 289 | 313 | |
| | 1976 | 320 | 4 | 4 | 17 | 295 | 221 | 8 | 40 | 24 | 197 | 205 | | 494 | 577 | |
| | 1981 | 2,699 | 25 | 28 | 19 | 2,627 | 1,970 | 48 | 337 | 193 | 1,777 | 1,830 | 50 | 2,274 | 2,465 | 4.8 |
| D | 1966 | 103 | 2 | 2 | 10 | 89 | 67 | 4 | 13 | 8 | 59 | 63 | | 63 | 63 | |
| | 1971 | 121 | 2 | 2 | 9 | 108 | 81 | 4 | 15 | 9 | 72 | 76 | | 139 | 151 | |
| | 1976 | 140 | 2 | 2 | 9 | 127 | 95 | 4 | 18 | 11 | 84 | 88 | | 227 | 267 | |
| | 1981 | 3,406 | 31 | 35 | 24 | 3,316 | 2,487 | 61 | 426 | 244 | 2,243 | 2,309 | 50 | 2,486 | 2,576 | 5.0 |

1 Unrecovered depletion in 1961 is $37 per acre.

2 Total unrecovered road depreciation on 245 acres in 1961 is $9,931; the average unrecovered road depreciation is $41 per acre.

3 Calculated at $2.25 per thousand board feet for thinnings and $0.40 per thousand for final clear cut.

4 Stumpage revenue less depletion, depreciation, and direct selling expense

5 Taxable gain less 25 percent, the tax rate on the gain.

6 Road maintenance is calculated at $1 per thousand board feet.

7 Yield tax is 12-1/2 percent of stumpage revenue.

8 These expenses are offset against ordinary income, which is taxed at 50 percent. After-tax cost, therefore, is one-half the actual cash outlay.

9 Net stumpage revenue after tax on gain less total after-tax property expenses.

10 Net income from timber property plus depletion and road depreciation.

11 Cash flow less regeneration cost. Interest calculated at 3.5 percent, the expected after-tax return on the best comparable investment alternative of owner.

12 The after-tax earning rate on the owner's best alternative investment for the net cash flow ($997) generated by liquidation of stand B in 1961.

# The Management Decision

Straightforward application of the 3.5-percent return criterion led to a decision to hold stand B and a choice between plans B, C, and D.

The decision to hold was based upon an expected rising price for young-growth Douglas-fir stumpage. Accordingly, as much attention will have to be given to checking stumpage prices from year to year as to the continued silvicultural care of the stand. Since the internal rates of return for plans B, C, and D all substantially exceed the guiding rate, a somewhat lower price rise than that assumed will satisfy the guiding rate criterion. Any strong evidence against at least partial attainment of the 1981 price expectation, however, would become a criterion for reconsidering the decision to hold.[6]

According to the analysis, plan C is somewhat superior to plan B due apparently to the capture of mortality in plan C, earlier harvest of the slowest growing trees, and somewhat less growing stock after 1961. From the viewpoint of cumulative net cash flow, the difference between plans B and C is only $19, or less than $1 per acre per year. This small difference in net cash flow is attributable to the heavy thinning removals at prices below those assumed for 1981 and the assumption of a slight loss of gross growth in association with the heavy thinnings. For practical purposes, plans B and C are regarded as equally good.

Plan D shows a net cash flow of $130 per acre more than plan B. This difference is substantial and, expanded to the total area of stand B, amounts to $18,850. The advantage in plan D appears to be in the early capture of mortality through light thinning without significant loss of growth per acre and in early removal of trees with very poor growth rates. More volume is carried to 1981 when stumpage prices are assumed to be at the highest level in the next 20 years. Because some mortality is inevitable, even in stands thinned as carefully as stand B, some provision for light thinning seems to be prudent. With other assumptions for plan D equally as tenable as corresponding ones for plans B and C, the difference between plan D and plan B is taken as real and practical.

Thus, the recommended management for stand B is continued light thinning at 5-year intervals, emphasizing harvest of potential mortality and the very slowest growing trees. For practical marking purposes, the slowest growing trees are defined as those whose volume growth percent is expected to fall below 1.5 in the next 5-year thinning period. The 1.5 percent is equivalent to about 3.5 percent in expected value growth. This is based upon the approximate 2-percent difference in the internal earning rates of plans B, C, and D attributable to the rising price expectation.

[6] Under the assumption of constant stumpage prices, it is clear that stand B reached financial maturity and, therefore, harvest age sometime before 1961. From a cash flow viewpoint, even though management of stand B with thinnings may have been superior to holding it without thinning to 1961, the earnings on the capital investment had obviously dropped below 3.5 percent before 1961. For owners with after-tax guiding rates of 3.0 percent or lower, however, holding stand B beyond 1961 could be an attractive alternative even under the assumption that prices will remain constant.

# APPENDIX

## Computation of Stumpage Prices

Schedule A, column 10, presents the estimated stumpage price by d.b.h. class for second-growth Douglas-fir on McCleary Experimental Forest. The basic data and calculated values used to estimate stumpage price by d.b.h. class are also included.

Schedule B presents estimated stumpage by d.b.h. class and year under the assumption that the stumpage price of 16-inch-d.b.h. Douglas-fir will rise to $30 per thousand board feet in 1981. A linear increase is assumed for the time period between 1961 and 1981.

### PROCEDURE IN DEVELOPING SCHEDULE A

In schedule A, columns 1, 2, and 3 give the expected log grade recovery in Scribner board feet from average trees in each d.b.h. class. Three log grades are recognized: SFP (suitable for peeling), No. 2 saw log, and No. 3 saw log, with values of $60, $48.50, and $38.25 per thousand board feet, Scribner rule, respectively. These are log grade prices currently available in the McCleary Experimental Forest market area.

The average log value per thousand board feet, Scribner rule, computed from the foregoing log prices, is given for each d.b.h. class in column 5. These are adjusted in column 6 to reflect actual market experience in 1961. The tree of average d.b.h. for the 1961 thinnings was 14.6 inches. The average price received for logs from the 1961 thinnings was $46 per thousand board feet. The interpolated log value for a tree 14.6 inches in size on the basis of the computed tree values per thousand board feet in column 5 is $41.73. The ratio 46.00/41.73, or 1.1023, is applied to all computed values in column 5 to derive adjusted tree values per thousand board feet in column 6.

In column 7, the logging costs are tabulated for southern pine trees as reported in table 74 of U. S. Department of Agriculture Technical Bulletin 861. These costs do not apply to Douglas-fir, nor are they current cost values. However, the cost relationship between d.b.h. classes is assumed to apply approximately to Douglas-fir trees of the same d.b.h. The cost relationship between d.b.h. classes is expressed as an index in column 8. The index is calculated as a percent of the logging cost for 14.6-inch trees.

Logging costs by d.b.h. for the McCleary Experimental Forest, column 9, are estimated by applying the logging cost index to the average cost, $30.54, experienced in 1961 in logging thinnings whose average d.b.h. was 14.6 inches.

Estimated McCleary stumpage values are then developed in column 10 by subtracting the estimated logging cost per thousand board feet in column 9 from the corresponding adjusted log values in column 6.

### PROCEDURE FOR DEVELOPING SCHEDULE B

Stumpage price relatives by d.b.h. class are calculated in column 1, schedule B, from the 1961 McCleary stumpage prices determined in schedule A. The stumpage price relative for 16-inch trees is taken as 100; price relatives for other d.b.h. classes are expressed as a percent of the price for 16-inch trees.

The stumpage prices for 16-inch trees in 1966, 1971, 1976, and 1981 are interpolated on a straight-line basis between the expected $30 price in 1981 and the 1961 price. Stumpage prices for other d.b.h. classes in 1966, 1971, 1976, and 1981 are derived by applying the stumpage price relatives to the price established for 16-inch trees in each respective year.

This method assumes that relative stumpage prices by d.b.h. class remain unchanged between 1961 and 1981.

## SCHEDULE A

### Estimated stumpage price for second-growth Douglas-fir by d.b.h. class for McCleary Experimental Forest, 1961

| D.b.h. (inches) | Log grades | | | Total volume | Log value[1] per M bd. ft. | Adjusted log value per M bd. ft. | Southern pines logging cost[2] | | McCleary Experimental Forest | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SFP | No. 2 | No. 3 | | | | Per M bd. ft. | Index | Logging cost per M bd. ft. | Stumpage value per M bd. ft. |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| | — — — | Bd. ft. | — — — | Bd. ft. | Dollars | Dollars | Dollars | Percent | Dollars | Dollars |
| 12 | -- | -- | 142 | 142 | 38.25 | 42.16 | 4.99 | 145.5 | 44.44 | - 2.28 |
| 13 | -- | -- | -- | 178 | 38.25 | 42.16 | 4.15 | 121.0 | 36.95 | 5.21 |
| 14 | -- | 54 | 164 | 218 | 40.79 | 44.96 | 3.64 | 106.1 | 32.40 | 12.56 |
| 14.6 | -- | -- | -- | -- | 41.73 | 46.00 | 3.43 | 100.0 | 30.54 | 15.46 |
| 15 | -- | -- | -- | 262 | 42.36 | 46.69 | 3.29 | 95.9 | 29.29 | 17.40 |
| 16 | -- | 170 | 136 | 306 | 43.94 | 48.44 | 3.07 | 89.5 | 27.33 | 21.11 |
| 17 | -- | -- | -- | 358 | 44.70 | 49.27 | 2.92 | 85.1 | 25.99 | 23.28 |
| 18 | -- | 288 | 122 | 410 | 45.45 | 50.10 | 2.80 | 81.6 | 24.92 | 25.18 |
| 19 | -- | -- | -- | 462 | 46.14 | 50.86 | 2.69 | 78.4 | 23.94 | 26.92 |
| 20 | -- | 441 | 85 | 526 | 46.84 | 51.63 | 2.58 | 75.2 | 22.97 | 28.66 |
| 21 | -- | -- | -- | 594 | 47.88 | 52.78 | 2.47 | 72.0 | 21.99 | 30.79 |
| 22 | 100 | 481 | 84 | 665 | 48.93 | 53.94 | 2.36 | 68.8 | 21.01 | 32.93 |
| 23 | -- | -- | -- | 732 | 49.55 | 54.62 | 2.24 | 65.3 | 19.94 | 34.68 |
| 24 | 150 | 626 | 36 | 812 | 50.17 | 55.30 | 2.15 | 62.7 | 19.15 | 36.15 |
| 25 | -- | -- | -- | 899 | 50.32 | 55.47 | 2.07 | 60.3 | 18.42 | 37.05 |
| 26 | 200 | 747 | 36 | 983 | 50.46 | 55.62 | 2.00 | 58.3 | 17.80 | 37.82 |
| 27 | -- | -- | -- | 1,059 | 51.02 | 56.24 | 1.95 | 56.9 | 17.38 | 38.86 |
| 28 | 340 | 774 | 36 | 1,150 | 51.58 | 56.86 | 1.91 | 55.7 | 17.01 | 39.85 |
| 29 | -- | -- | -- | 1,233 | 51.78 | 57.08 | 1.88 | 54.8 | 16.74 | 40.34 |
| 30 | 405 | 929 | -- | 1,334 | 51.99 | 57.31 | 1.86 | 54.2 | 16.55 | 40.76 |
| 31 | -- | -- | -- | 1,422 | 52.05 | 57.37 | [3]1.85 | 53.9 | 16.46 | 40.91 |
| 32 | 475 | 1,038 | -- | 1,513 | 52.11 | 57.44 | [3]1.85 | 53.9 | 16.46 | 40.98 |

[1] Log prices = $60 for SFP; $48.50 for No. 2; $38.25 for No. 3.
[2] From table 74 of: Reynolds, R. R., Bond, W. E., and Kirkland, Burt P. Financial aspects of selective cutting in the management of second-growth pine-hardwood forests west of the Mississippi River. U. S. Dept. Agr. Tech. Bul. 861, 118 pp., illus. 1944.
[3] Estimated for these diameter classes.

## SCHEDULE B

### Expected stumpage prices for second-growth Douglas-fir on McCleary Experimental Forest in 1966, 1971, 1976, and 1981

| D.b.h. (inches) | Stumpage price relatives | Expected stumpage prices per thousand board feet in — | | | | |
|---|---|---|---|---|---|---|
| | | 1961 | 1966 | 1971 | 1976 | 1981 |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | | — — — — — — — — — Dollars — — — — — — — — — | | | | |
| 15 | 82.4 | 17.40 | 19.22 | 21.06 | 22.89 | 24.72 |
| 16 | 100.0 | 21.11 | 23.33 | 25.56 | 27.78 | 30.00 |
| 17 | 110.3 | 23.28 | 25.73 | 28.19 | 30.64 | 33.09 |
| 18 | 119.3 | 25.18 | 27.83 | 30.49 | 33.14 | 35.79 |
| 19 | 127.5 | 26.92 | 29.75 | 32.59 | 35.42 | 38.25 |
| 20 | 135.8 | 28.66 | 31.68 | 34.71 | 37.73 | 40.74 |
| 21 | 145.9 | 30.79 | 34.04 | 37.29 | 40.53 | 43.77 |
| 22 | 156.0 | 32.93 | 36.39 | 39.87 | 43.34 | 46.80 |
| 23 | 164.3 | 34.68 | 38.33 | 42.00 | 45.64 | 49.29 |
| 24 | 171.2 | 36.15 | 39.94 | 43.76 | 47.56 | 51.36 |
| 25 | 175.5 | 37.05 | 40.94 | 44.86 | 48.75 | 52.65 |
| 26 | 179.2 | 37.82 | 41.81 | 45.80 | 49.78 | 53.76 |
| 27 | 184.1 | 38.86 | 42.95 | 47.06 | 51.14 | 55.23 |
| 28 | 188.8 | 39.85 | 44.05 | 48.26 | 52.45 | 56.64 |
| 29 | 191.1 | 40.34 | 44.58 | 48.85 | 53.09 | 57.33 |
| 30 | 193.1 | 40.76 | 45.05 | 49.36 | 53.64 | 57.93 |
| 31 | 193.8 | 40.91 | 45.21 | 49.54 | 53.84 | 58.14 |
| 32 | 194.1 | 40.98 | 45.28 | 49.61 | 53.92 | 58.23 |

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# Top and root MOISTURE CONTENT

## of stored Douglas-fir planting stock

BY ROBERT F. TARRANT

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE · FOREST SERVICE

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FOREST SERVICE
JUNE 1964

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# INTRODUCTION

In the Pacific Northwest, Douglas-fir *(Pseudotsuga menziesii)* is usually planted in late fall or early spring when high soil moisture and cool, rainy weather prevent plant desiccation. Under optimum conditions, healthy-appearing seedlings, often dripping with water, are carefully placed into soil which is at or near field moisture capacity and are almost continually wetted with rain for several months. Yet, with cessation of rainfall and onset of warm weather in late spring or early summer, many such seedlings may show signs of distress and soon die.

Because the first warm, dry days in late spring or early summer frequently coincide with seedling mortality, death of seedlings is often subjectively attributed to excessive heat or drought. However, some findings point to the possibility that preplanting desiccation, a condition most difficult to detect visually, may sometimes be responsible for early season mortality.

Original purpose of this study was to find whether seedlings maintained their initial moisture content during 24 weeks' storage at 35° F. and 95-percent relative humidity. After only 8 weeks, however, normal cold storage conditions were interrupted, because changes in storage schedules and shifts of stored stock necessitated frequent opening of the cooler and some intermittent operation of the refrigeration system. Because analysis of seedlings sampled to that time indicated that the relationship between top and root moisture appeared to vary with changes in total seedling moisture content, the remaining seedlings stored for study were left in the coldroom where they slowly lost moisture in the absence of normal storage conditions.

# STUDY METHODS

Seedlings were collected at Wind River Nursery[1] in late October during routine packing of stock of a Willamette National Forest seed source. Thirty-five lots of 10 seedlings each were removed at random from a total of about 2,000 passing over the conveyor belt and were randomly combined into 7 groups of 50 trees each. One group was taken for immediate analysis, and the remaining six were marked and placed at random within one shipping bundle of 2,000 seedlings. The roots were packed in moist cedar shavings (shingle tow) and the tops were exposed outside the bundle wrapping. After being tied, the bundle was stored in a cooler.

At 4-week intervals, a group of 50 trees was removed from the bundle. Each seedling was severed at ground line, and resulting top and root portions were placed in separate sealed containers. Container and contents were weighed to the nearest 0.01 gram, after which the top or root portion was removed from the container, washed over filter paper to collect soil particles, then dried to a constant weight at 95° C. Weight of adhering soil and its moisture was subtracted from gross fresh weight to enable calculation of ovendry weight of clean tops and roots. Moisture content, as percent of dry weight, was calculated for each top ($M_t$), root ($M_r$), and entire seedling (MC).

[1]Operated by the U.S. Forest Service at Carson, Wash.

# RESULTS

## Top and Root Moisture Content of Seedlings Stored 0 to 8 Weeks

The relation of $M_t$ and $M_r$ to length of time seedlings were in normal storage was studied in a regression analysis which included data for only the first 8 weeks. When seedlings were packed, $M_t$ and $M_r$ were essentially the same (table 1). After both 4 and 8 weeks' storage, $M_t$ and $M_r$ had increased significantly over the previous observation, but $M_r$ had increased at a faster rate (fig. 1). It is thus evident that seedling moisture content was not impaired by about 2 months' cold storage.

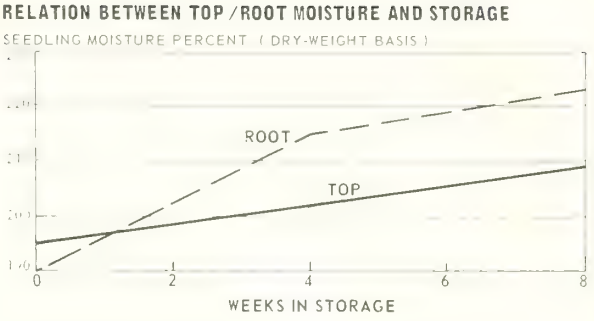
Table 1. – Average moisture content and coefficient of variation of seedling parts for each periodic sampling

| Weeks stored[1] | Moisture content of plant part | | | Coefficient of variation[2] | | |
|---|---|---|---|---|---|---|
| | Whole | Top | Root | Whole | Top | Root |
| | Percent | | | | | |
| 0 | 191 | 195 | 190 | 12 | 15 | 17 |
| 4 | 207 | 202 | 215 | 11 | 17 | 16 |
| 8 | 215 | 209 | 223 | 13 | 16 | 17 |
| 12 | 136 | 154 | 115 | 16 | 18 | 20 |
| 16 | 147 | 171 | 121 | 9 | 11 | 15 |
| 20 | 58 | 75 | 39 | 20 | 25 | 40 |
| 24 | 94 | 115 | 78 | 21 | 30 | 36 |

[1] Between 0 and 8 weeks, seedlings were stored at 35° F. and 95- percent relative humidity. After 8 weeks, this environment was only intermittently maintained, which allowed slow drying of seedlings.

[2] Standard deviation expressed as percent of the mean dry weight.

Figure 1.—Relation between top and root moisture and number of weeks in storage at 35° F. and 95-percent relative humidity.




Hellmers (5) reported that moisture content of stored stock was higher than that of freshly dug stock for both 1-1 Jeffrey pine (*Pinus jeffreyi*) and 2-0 ponderosa pine (*Pinus ponderosa*). He concluded that the difference might be due to drying conditions in field in contrast to storage environment, which includes moist packing material about roots and protection of tops from desiccating air movement. Possible sources of water gained by seedlings in storage, aside from that in the packing material, include moisture in the atmosphere and in soil particles adhering to roots.

An increase in water content soon after seedlings are placed in cool, humid storage might be explained simply as an adjustment of water losses during lifting and packing. However, such an adjustment should normally take place in a short time. If observed rise in moisture percent over a period of 8 weeks is real, then some other factor, perhaps metabolic plant activity, might have influenced moisture measurements. Possible effects include a decrease in plant dry weight through respiration of reserve foods or a gradual increase in hygroscopic compounds resulting from transformations within the plant of starch, reserve protein, and fats.

The continued rise of seedling moisture percent over 8 weeks might also be explained on the basis of respiration effects. When roots are tightly wrapped, as in a storage bundle, high $CO_2$ concentrations often develop. In some plants, an increase in $CO_2$ concentration of their environment slows absorption of water (8). Thus, if $CO_2$ had accumulated substantially in the bundle of seedlings studied, the water deficit existing at time of packing might have been only slowly overcome during the 8-week storage period.

## Factors Affecting Ratio of Top/Root Moisture in Seedlings Stored 0 to 24 Weeks

Data for all 350 seedlings sampled periodically for 24 weeks were analyzed by multiple regression (4). The dependent variable for this analysis was the ratio (R) of top root moisture percent, where $R = \frac{M_t}{M_r}$.

Independent variables were:

1. Total seedling moisture percent (MC)
2. Total seedling weight (W)
3. Weeks in storage (P)
4. MC x P
5. $MC^2$
6. $W^2$

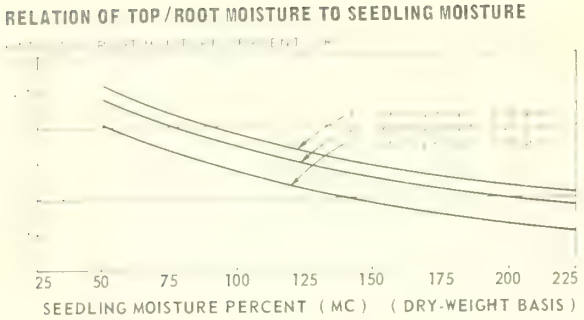



Figure 2.—Relationship of top/root moisture percent (R) to seedling moisture percent (MC).

Independent variables 3, 4, and 6 failed to account for a significant proportion of the total variation in R. The equation of best fit, which led to the curves in figure 2, was taken as:

$$R = 3.509 - 0.0185MC - 0.2017W + 0.0000365MC^2$$

The mathematical model underlying the regression analysis is based on the assumption that each seedling represents an independent observation. Actually, seedlings were stored within the bundle in groups of 50, so this assumption of independence is not completely tenable.

When seedlings were bundled at a MC of 191 percent, top moisture percent was 195, that of roots was 190, and R was 1.03, indicating that water was nearly balanced within the plant. When plants lost water, however, R increased – tops contained relatively more water than roots. At a MC of 80 percent, top moisture was 107 percent but root moisture was only 53 percent (R = 2.00) and seedlings had lost nearly 70 percent of their original water.

Seedling size (dry weight) appeared to affect the value of R. Compared with the average seedling of 1.27 grams, smaller seedlings had a higher R – the disparity between top and root moisture was greater at any given MC. On the other hand, larger seedlings displayed a lower R, indicating that they might better resist changes in internal water balance as they dried. This finding, however, is only tentative. The observed effect of seedling size on R may be real, but again it may only reflect differences in plant succulence due to size.

# DISCUSSION

Varying need for water among various plant tissues is probably one explanation for the widening difference between top and root moisture during seedling drying. Stored seedlings, presumably like those growing in soil, transpire moisture whenever there is a vapor-pressure gradient from leaves to air. As long as roots remain in contact with an adequate source of moisture, foliage transpiration losses are replaced by water absorbed by roots from their surroundings. When the water source becomes curtailed, as in drier packing material or soil, transpiration continues, although at a reduced rate. Plant tissues which can produce the highest diffusion-pressure deficit then obtain water from those having lower deficits *(7)*.

Results of the current study show that as Douglas-fir seedlings dry, root moisture becomes substantially lower than top moisture. This consistent relationship indicated that subjective

evaluation or even actual determination of seedling top moisture may not be a good measure of the extent of whole plant desiccation.

Apparently, foliage samples can be safely used to determine total moisture content of only those seedlings freshly dug from moist soil. However, if plants have been subjected to drying after lifting, then sampling only top or needle moisture might lead to an erroneous estimate of total seedling moisture and its distribution within the plant.

Another precaution indicated by this study pertains to the method used for sampling seedlings. Despite random selection of trees from the conveyor belt after culling, seedling size varied widely, both within and between 50-tree sample groups (table 2). Thus, in future research on moisture content of nursery seedlings, samples should be drawn on a predetermined basis, such as weight or stem diameter, to achieve greater uniformity of seedling size.

Table 2. – Average ovendry weight and coefficient of variation of seedling parts for each periodic sampling

| Weeks stored | Weight of plant part | | | Coefficient of variation[1] | | |
|---|---|---|---|---|---|---|
| | Whole | Top | Root | Whole | Top | Root |
| | Grams | | | Percent | | |
| 0 | 1.35 | 0.75 | 0.60 | 44 | 49 | 45 |
| 4 | 1.19 | .65 | .54 | 47 | 52 | 45 |
| 8 | .99 | .53 | .46 | 55 | 55 | 60 |
| 12 | 1.52 | .83 | .69 | 56 | 58 | 52 |
| 16 | 1.15 | .61 | .54 | 37 | 43 | 35 |
| 20 | 1.21 | .66 | .55 | 58 | 58 | 61 |
| 24 | 1.41 | .73 | .68 | 54 | 66 | 49 |

[1] Standard deviation expressed as percent of the mean.

If the observed relation of top/root moisture percent and seedling size is valid, it indicates that in further research on tree seedling moisture relationships we must take into account size of plants with which we are working. First need is for detailed physiological studies to determine whether the relationship between tree size and moisture balance was indeed real or was peculiar only to the planting stock used in the experiment. Additional research of the type proposed might well be associated with studies such as that of Stone and Schubert *(10)* in which physiological condition of the seedling and various parts of the root system were considered.

Many occasions for seedling desiccation occur during lifting, grading, packing, storage, transit to planting site, and planting. Further, in dry, windy weather, newly planted seedlings may lose moisture more rapidly than their root systems can replace it. Seriousness of moisture loss in planting stock, including Douglas-fir, was brought out by Aldhous *(1)*:

> Analysis of the causes of death of plants following planting showed that bad planting, severe drought following planting and damage during transit from nursery to planting area, each have contributed to losses following planting. In most cases, the primary cause of death was desiccation . . . .

Previous research helps interpret possible effects of increasing top/root moisture imbalance when Douglas-fir seedlings lose water. Although the work cited in the following paragraphs deals with plants growing in soil in contrast to nursery stock stored in bundles, moisture adjustment within the plant probably proceeds similarly in both cases.

The needle moisture content that represents a "lethal level" or threshold of plant death from desiccation was studied by Parker *(9)*. In several conifers including Douglas-fir, needles remained viable, by the tetrazolium test, until 50 percent or more of their original weight, dry tissue basis, had been lost. A Douglas-fir needle moisture content of 68 percent was associated with 100-percent viability, but one of 39 percent indicated total loss of needle viability.

Needle viability, however, is not necessarily a measure of whole plant condition. According to Brix *(2)*, a leaf moisture content of 110 percent was critical for loblolly pine *(Pinus taeda)* seedlings, because plants dried below this level did not recover after watering. He concluded that significant changes in the roots restricted water transport to the leaves in desiccated plants (needle moisture less than 110 percent), because leaves with water content as low as 76 percent regained turgidity when either detached leaves or plants with roots excised were placed with the cut end in water. Brix felt that the most likely explanation for the critical increase in root resistance to water uptake and transport was that increasing dehydration may have affected permeability of living root tissues and caused breaks in the water columns.

A critical leaf moisture content of 110 percent was also cited by Faulkner and Aldhous *(3)*. Survival of stored tree seedlings of 13 species, including Douglas-fir, was more than 70 percent when moisture content (presumably of needles) was 110 percent or more, but less than 5 percent at a moisture level of 40 percent or less. Between these limits, the relationship of survival to moisture content was linear.

Findings by Kramer *(6)* are pertinent to interpretation of current study results. He reported that even after roots of loblolly pine seedlings were killed with hot water, the tops would remain "alive" and unwilted for 2 weeks or more because considerable quantities of water were absorbed from the soil through dead root systems. He believed that water would continue to be absorbed

until the dead root systems were destroyed by decay. Kramer also felt that minerals would probably be absorbed through dead roots in amounts approximately proportional to quantity of water absorbed.

Thus, we have evidence that tops of desiccated seedlings contain substantially more water than roots do; that deleterious effects of desiccation probably occur first in roots; and that living roots are not necessary for maintenance of "live" plant foliage over a substantial period of time. We might, therefore, speculate as to the true cause of some seedling deaths in the late spring or early summer after planting.

A Douglas-fir seedling may be in apparently good condition for planting, judged subjectively from needle turgidity, color, and general appearance. This might be true especially during rainy weather or when plant surfaces are otherwise well wetted. However, if significant amounts of water were lost from the plant at some time between nursery lifting and field planting, roots might be injured or even killed. However, dead roots might continue to supply tops adequately with water during cool, rainy weather, masking for awhile any destruction of active root functioning.

Seedlings might thus continue to appear alive for some time after planting, even though the roots were mortally damaged. But at the onset of summer heat and soil moisture stress, foliage would also die and turn brown. Coincidence of recognizable seedling death with seasonally increased air temperature and decreased soil moisture, in this case, could lead the casual observer to erroneously assume heat and drought to be the causes of mortality.

## SUMMARY

Top and root moisture percent, dry-weight basis, was studied in cold-stored, 2-year-old Douglas-fir seedlings.

During an initial 8-week storage period at 35° F. and 95-percent relative humidity, plants gained moisture. Roots apparently gained at a faster rate than tops.

When seedlings were subsequently dried slowly, roots lost moisture more rapidly than tops. The difference between top and root moisture percent at a given whole seedling moisture percent was greater for smaller seedlings and less for those of larger size.

A hypothesis, also supported by evidence from other research, is suggested that the difference in drying rates of tops and roots explains some otherwise puzzling spring or early summer mortality of seedlings planted under optimum conditions of soil moisture and weather.

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Differential drying of tops and roots may explain some puzzling early-season mortality of planted seedlings.

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# Sampling egg populations of WESTERN HEMLOCK LOOPER in coastal forests

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## SUMMARY

The western hemlock looper periodically causes severe damage in coastal forests of Oregon, Washington, and British Columbia. Improved survey methods are needed to detect infestations before damage occurs and to express hazard by estimates of egg populations. Cooperative sampling studies by the Forest Service and Weyerhaeuser Co. were conducted in the winter of 1962-63 to improve existing survey techniques.

Results show that the best sampling units for detecting looper infestations are mossy log surfaces and bole sections at breast height, both of which are easily accessible from the ground. Egg deposition is associated with moss on roughened bark and flat lichens on smooth bark. Numbers of eggs found on limbs are related to numbers of eggs on boles, when expressed on the basis of area of moss. The best method for estimating egg populations is to fell the tree and sample the bole at midcrown; this verifies a finding based on studies in British Columbia. Estimating populations in the tree from ground-site samples--a method previously unexplored--does not appear efficient.

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# Sampling egg populations of WESTERN HEMLOCK LOOPER in coastal forests

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August 1964

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FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

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## INTRODUCTION

Outbreaks of western hemlock looper (Lambdina fiscellaria lugubrosa (Hulst)) occur at intervals of 11 to 17 years in coastal areas of Oregon, Washington, and British Columbia. They arise suddenly, persist generally for 3 years, and cause severe damage. Most outbreaks take place in mature stands of western hemlock (Tsuga heterophylla (Raf.) Sarg.). Intermixed Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), Sitka spruce (Picea sitchensis (Bong.) Carr.), Pacific silver fir (Abies amabilis (Dougl.) Forbes), and western redcedar (Thuja plicata Donn) are also attacked. One year's heavy feeding by the looper on western hemlock can result in tree mortality.

If timber losses are to be kept to a minimum, potential outbreaks must be detected at an early stage and evaluated on a biological basis so that direct control can be applied promptly, if needed. By the time hemlock looper damage is visible from the air, an outbreak is usually well underway. Therefore, detection efforts should be aimed at locating appreciable populations before damage occurs, following with a biological evaluation to determine whether tree damage will be significant.

These survey efforts can best be made during the winter by sampling the egg stage. The fact that eggs are deposited on debris and shrubs in the understory area, as well as on overstory trees, causes problems in sampling. Analysis of egg distribution is necessary in order to develop sound sampling techniques for detection and evaluation surveys.

In the past, sampling of egg populations has been directed either to mossy surfaces accessible from the ground or overstory trees, but never to both. In Oregon and Washington, abundance of looper eggs on moss collected at random from various ground locations has been used to indicate relative hazard to stands and probable need for control.[1/] Samples of moss were dried and processed mechanically to separate the eggs from the moss for rapid counting. However, the relation of numbers of eggs found on these samples to populations in overstory trees was not determined. In British Columbia, studies by Thomson[2/] indicated that with relatively low populations the greatest number of eggs on overstory trees occurred on the bole at midcrown. It was recommended that egg sampling be restricted to the bole in the middle part of the crown and

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[1/] Unpublished reports on file U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station and Region 6 National Forest Resource Management, Portland, Oreg.

[2/] Thomson, M. G. Egg sampling for the western hemlock looper. Forestry Chron. 34(3): 248-256. 1958.

that codominant trees be included in the sampling. Earlier, Kinghorn[3/] found that egg deposition on tree boles increased with height above ground and reached a maximum density at about the base of the crown. His analysis indicated that, by adjusting butt sample counts with the appropriate regression formula for the total height of the tree, a good estimate of the average number of eggs per sample for the tree should be obtainable. It was pointed out that butt sampling would save a great deal of time by eliminating the task of felling trees but that the method might not be applicable to subepidemic conditions.

Further study of the distribution of looper eggs both on overstory trees and on ground sites (shrubs and debris in the understory area) was needed to (1) improve detection methods and (2) devise a means of estimating the general level of egg populations. These aims were the basis for a cooperative study between the U.S. Forest Service and the Weyerhaeuser Co. during the winter of 1962-63. Results from improvement in sampling techniques are applicable to surveys of current infestations affecting large acreages of valuable hemlock timber in Oregon and Washington.

## OBJECTIVES

This western hemlock looper study was designed to answer the following questions:

1. What sampling unit is best to detect infestations?
2. What are the favored places for egg deposition on codominant western hemlock trees and on ground sites below these trees?
3. Which ground-site samples produce estimates representative of egg deposition on the tree and how do their costs compare with those of samples from the tree crown?

## METHODS

Sampling was restricted to codominant western hemlock trees 20 to 40 inches d.b.h., the common size range in a heavily infested area near Nemah, Wash. The sampling unit was the overstory tree and the area beneath its crown. It was prescribed that at least one understory shrub of huckleberry (Vaccinium spp.) and one mossy log occur within the crown projection of each overstory tree. Surveys had previously shown some egg deposition to occur on huckleberries. Subsampling was used to show relative numbers of eggs on the tree at different vertical and horizontal positions and on various representative ground sites. Four trees were sampled as a cluster at each of three locations in the

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[3/] Kinghorn, J. M. Western hemlock looper egg sampling. Canada Dept. Agr. Forest Biol. Div. Bimo. Prog. Rpt. 8(3): 3-4. 1952.

infested area. Defoliation of these trees from 1962 feeding, estimated with field glasses, ranged from 10 to 95 percent and averaged about 62 percent. Characteristics of the 12 sample trees are listed in table 1.

Table 1.--Descriptive data on 12 codominant western hemlock trees sampled for hemlock looper eggs near Nemah, Wash., in November and December 1962

| Cluster No. | Tree No. | D.b.h. | Height | | Estimated defoliation |
|---|---|---|---|---|---|
| | | | Total | Base of crown | |
| | | Inches | Feet | Feet | Percent |
| 1 | 1 | 36 | 150 | 80 | 25 |
| | 2 | 31 | 135 | 66 | 80 |
| | 3 | 22 | 120 | 45 | 50 |
| | 4 | 20 | 135 | 70 | 60 |
| 2 | 5 | 38 | 115 | 48 | 90 |
| | 6 | 41 | 135 | 38 | 95 |
| | 7 | 27 | 120 | 45 | 40 |
| | 8 | 21 | 115 | 64 | 10 |
| 3 | 9 | 25 | 120 | 44 | 70 |
| | 10 | 20 | 115 | 45 | 40 |
| | 11 | 34 | 145 | 36 | 90 |
| | 12 | 20 | 120 | 35 | 95 |

The tree was sampled at lower crown, midcrown, and upper crown by taking, at each crown position, three 6-inch-long sections from each of two limbs and two 6x12-inch bark samples from the bole. Limb sections were equally spaced between the base and tip of the branch. In each crown position, limbs and bole areas sampled were on opposite sides of the tree. The bole was also sampled at breast height, using two 6x12-inch sections from opposite sides of the tree. Foliage was not sampled; however, it was inspected since Hopping[4/] reported finding some eggs deposited on the undersides of needles. Ground sites sampled were: (1) stem of huckleberry, using three equally spaced 6-inch sections; (2) limb stubs extending vertically from a mossy log, using two 6-inch sections; (3) surface of a mossy log, three 2x4-inch sections; and (4) mossy ground, three 2x4-inch sections.

[4/] Hopping, G. R. An account of the western hemlock looper, Ellopia somniaria Hulst, on conifers in British Columbia. Sci. Agr. 15: 12-29. 1934.

Dimensions and numbers of subsample units were selected to equalize examination time for different units and at the same time to obtain appreciable numbers of eggs. Figure 1 shows the sampling scheme diagrammatically.

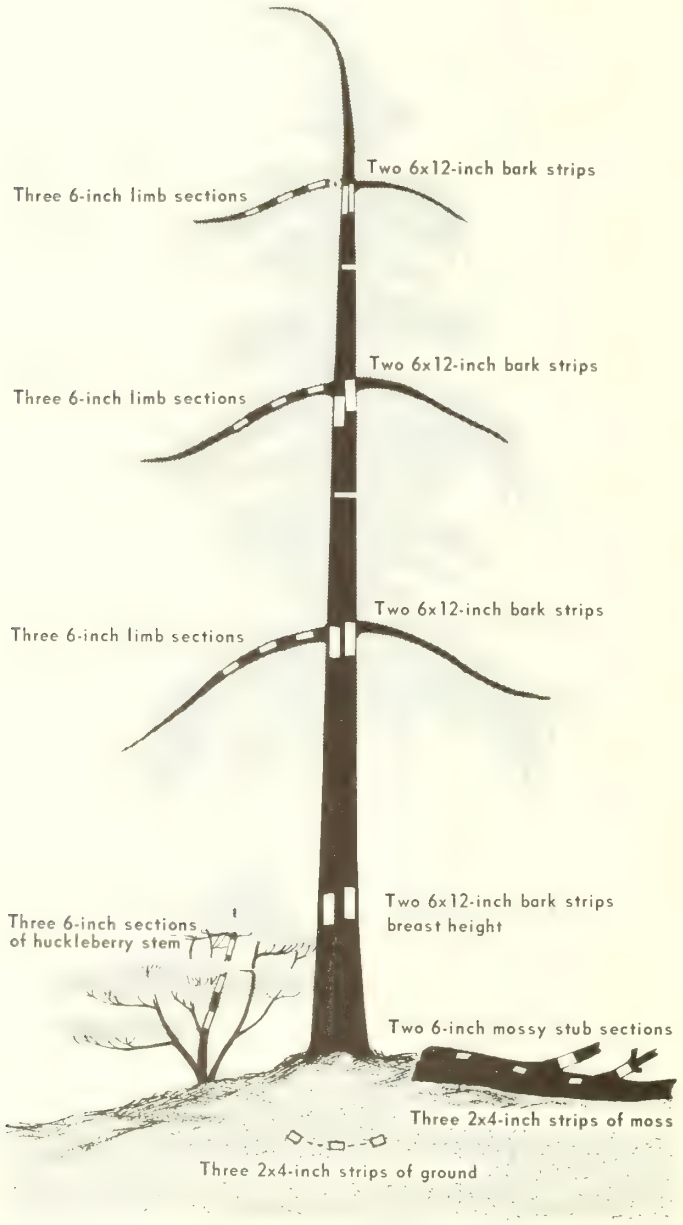


Figure 1.--Diagram of sample tree and its understory area, showing location of subsamples.

Ground sites and boles at breast height were sampled first; then trees were felled and the crowns sampled. Sections of mossy log and mossy ground were cut with a sharp knife and later trimmed to the proper size with scissors. Sections of huckleberry stem, stubs on logs, and limbs on trees were cut with a pruning saw, while bole sections were removed with a chain saw. Examination of subsamples was made with naked eye, stand magnifiers, and binocular microscopes, without testing the accuracy of the three methods. The following data were recorded for each subsample: dimensions of units including average diameter of limb and stem sections, exposure, estimates of percent of "moss" coverage of the sample surface, a rough description of "mosses" and lichens present, numbers of new looper eggs, and time spent in examination. Numbers of old looper eggs were also recorded but not used in any way.

Average costs in man-hours of examining each subsample unit and total costs per site and per tree were determined. Additional cost of felling trees to obtain samples from the tree crown was estimated. Number of eggs on subsamples was expressed in three ways: (1) actual number on subsample, (2) number per 100 square inches of sample surface, and (3) number per 100 square inches of moss.

For detection surveys, subsample costs and variance among trees within clusters were combined to determine the relative efficiency of subsamples. Variance was based on actual numbers of eggs on subsamples. Analysis was aimed at selecting the best subsamples, from the standpoint of cost and variation, for showing whether or not appreciable infestation existed at a sample point.

The abundance of eggs on different substrata (moss, bark scales, lichens) was used as a guide in determining places favored for egg deposition and in selecting the best expression of egg counts for showing relationships between tree and ground locations for evaluation purposes. A tree index was constructed to show average egg populations for each tree. If expression was on the basis of actual number of eggs, the index was obtained by adding all egg counts on limb and bole samples. If expression was either on the basis of gross unit area or moss area, the number of eggs on sampling units was divided by the sum of the area of these units. Use of number of eggs per area, therefore, showed egg density on the sampling units.

Graphs were used to explore the relationship in egg deposition between the tree index and ground-site units, tree units and ground-site units, and boles and limbs within the tree. Correlation analysis was used when relationship appeared possible. Efficiency of using units from ground sites to represent egg populations on overstory trees was briefly explored.

## RESULTS

The various subsample units produced enough looper eggs to facilitate analysis and appeared to include the principal egg deposition sites. Omission of foliage from sampling was justified; no eggs were found on leaves during inspection of felled trees. Numbers of eggs found on the various subsamples taken from the 12 trees are shown in table 2.

Table 2.--Summary of numbers of hemlock looper eggs found and surface area of subsamples from 12 western hemlock trees and ground sites beneath these trees, Nemah, Wash., November-December 1962

| Tree No. | Bole at breast height | | Lower crown | | | | Middle crown | | | | Upper crown | | | | Huckleberry stems | | Stubs on logs | | Mossy logs | | Mossy ground | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Limbs | | Bole | | Limbs | | Bole | | Limbs | | Bole | | | | | | | | | |
| | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area |
| | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. |
| 1 | 58 | 144 | 203 | 165 | 0 | 144 | 337 | 202 | 11 | 144 | 39 | 132 | 7 | 144 | 48 | 41 | 2 | 57 | 3 | 24 | 19 | 24 |
| 2 | 104 | 144 | 40 | 195 | 20 | 144 | 123 | 202 | 48 | 144 | 1 | 162 | 10 | 144 | 2 | 30 | 11 | 57 | 11 | 24 | 3 | 24 |
| 3 | 5 | 144 | 38 | 146 | 29 | 144 | 99 | 156 | 3 | 144 | 20 | 125 | 79 | 144 | 0 | 24 | 14 | 90 | 1 | 24 | 1 | 24 |
| 4 | 22 | 144 | 23 | 151 | 33 | 144 | 27 | 140 | 67 | 144 | 0 | 118 | 1 | 144 | 26 | 57 | 4 | 49 | 3 | 24 | 2 | 24 |
| 5 | 122 | 144 | 222 | 200 | 40 | 144 | 33 | 172 | 64 | 144 | 0 | 130 | 13 | 144 | 121 | 57 | 108 | 28 | 8 | 24 | 6 | 24 |
| 6 | 282 | 144 | 32 | 292 | 101 | 144 | 103 | 261 | 194 | 144 | 9 | 139 | 44 | 144 | 23 | 57 | 61 | 26 | 1 | 24 | 5 | 24 |
| 7 | 101 | 144 | 91 | 203 | 93 | 144 | 40 | 147 | 21 | 144 | 0 | 134 | 8 | 144 | 111 | 42 | 76 | 21 | 2 | 24 | 0 | 24 |
| 8 | 76 | 144 | 14 | 177 | 22 | 144 | 7 | 174 | 1 | 144 | 0 | 129 | 0 | 144 | 1 | 62 | 3 | 28 | 1 | 24 | 0 | 24 |
| 9 | 46 | 144 | 152 | 166 | 173 | 144 | 34 | 145 | 88 | 144 | 0 | 73 | 0 | 144 | 11 | 47 | 4 | 57 | 2 | 24 | 5 | 24 |
| 10 | 44 | 144 | 35 | 139 | 113 | 144 | 55 | 160 | 93 | 144 | 3 | 98 | 25 | 144 | 7 | 24 | 71 | 49 | 1 | 24 | 1 | 24 |
| 11 | 37 | 144 | 29 | 344 | 32 | 144 | 90 | 141 | 10 | 144 | 86 | 154 | 22 | 144 | 10 | 35 | 3 | 47 | 9 | 24 | 2 | 24 |
| 12 | 2 | 144 | 20 | 193 | 11 | 144 | 61 | 153 | 27 | 144 | 6 | 64 | 2 | 144 | 2 | 49 | 5 | 113 | 3 | 24 | 0 | 24 |
| Total | 899 | 1,728 | 899 | 2,371 | 667 | 1,728 | 1,009 | 2,053 | 627 | 1,728 | 164 | 1,458 | 211 | 1,728 | 362 | 525 | 362 | 622 | 45 | 288 | 44 | 288 |
| Average | 74.9 | -- | 74.9 | -- | 55.6 | -- | 84.1 | -- | 52.2 | -- | 13.7 | -- | 17.6 | -- | 30.2 | -- | 30.2 | -- | 3.7 | -- | 3.7 | -- |

Examination of subsamples from the trees and ground sites required about 40 man-hours per tree. Time required to examine two bole sections was similar to that for three ground sections; considerably more time was required to examine a group of six limb sections. On a unit subsample basis, costs in terms of man-hours varied directly with the amount of moss present. Average man-hours required are shown below:

| | Units per tree | For single units | For all units per tree |
|---|---|---|---|
| | (Number) | (Man-hours) | (Man-hours) |
| Limb sites: | | | |
| Lower crown | 6 | 1.55 | 9.30 |
| Midcrown | 6 | 1.18 | 7.08 |
| Upper crown | 6 | .37 | 2.22 |
| Total | | | 18.60 |
| Bole sites: | | | |
| Breast height | 2 | 1.76 | 3.52 |
| Lower crown | 2 | 1.51 | 3.02 |
| Midcrown | 2 | 1.09 | 2.18 |
| Upper crown | 2 | .58 | 1.16 |
| Total | | | 9.88 |
| Ground sites: | | | |
| Stubs on log | 2 | 1.44 | 2.88 |
| Huckleberry stem | 3 | 1.09 | 3.27 |
| Mossy log | 3 | .69 | 2.07 |
| Ground | 3 | 1.05 | 3.15 |
| Total | | | 11.37 |
| Total for sample tree | | | 39.85 |

## Sampling for Detection Purposes

Analysis as to relative efficiency or precision of subsample estimates was based on costs and among-tree within-cluster variances. The additional cost of those units obtainable only by felling trees was derived by adding 0.5 man-hour to the examination costs on a tree basis. The analysis showed that two ground-site units--mossy logs and breast-high boles--were superior, for detection purposes, to units in the tree crown.

Variance among trees within clusters was expressed by the coefficient of variation, as shown in the following tabulation:

| Subsample: | Among-tree coefficient of variation |
|---|---|
| Boles, breast height | 0.81 |
| Boles, lower crown | .89 |
| Limbs, midcrown | .97 |
| Mossy logs | 1.02 |
| Log stubs | 1.06 |
| Limbs, lower crown | 1.09 |
| Boles, midcrown | 1.12 |
| Huckleberry stems | 1.24 |
| Boles, upper crown | 1.43 |
| Ground | 1.47 |
| Limbs, upper crown | 1.93 |

Two of the five units showing the least variation were from ground sites; a third was accessible from the ground. Breast-high bole sections were the least variable, while mossy logs and log stubs ranked fourth and fifth, respectively. Two subsamples from the tree crown--boles in lower crown and limbs at midcrown--were in second and third place.

The precision for each type of sampling unit relative to the precision for mossy logs, as shown below, was calculated by the formula:[5/]

$$\text{Relative precision} = \frac{V_1^2 C_1}{V_2^2 C_2}$$

where $V_1$ = coefficient of variation for mossy logs

$C_1$ = cost per single mossy log unit on a tree basis

$V_2$ = coefficient of variation for another type of sampling unit

$C_2$ = cost per single sampling unit of this other type on a tree basis.

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[5/] Based on: Cochran, W. G. Sampling techniques. Ed. 2, 413 pp. New York and London: John Wiley & Sons, Inc.

| | Relative precision |
|---|---|
| Subsample: | |
| Mossy logs | 100 |
| Boles, breast height | 93 |
| Boles, lower crown | 77 |
| Log stubs | 67 |
| Boles, midcrown | 64 |
| Boles, upper crown | 63 |
| Huckleberry stems | 43 |
| Ground | 32 |
| Limbs, midcrown | 30 |
| Limbs, upper crown | 21 |
| Limbs, lower crown | 18 |

The two units most efficient for use in detection surveys--mossy logs and breast-high boles--are both accessible from the ground. If trees were being felled for another purpose, such as right-of-way clearing, bole sections from the lower crown could be efficiently used. Use of log stubs might be justified if expense of transporting subsamples through the woods is high.

Standards for use in detection surveys to distinguish between endemic and epidemic populations are lacking. Since sampling was done under epidemic conditions in this study, the following estimates from table 2 can be used as a guide in recognizing an epidemic population level.

| | Subsample components | | Number of eggs | |
|---|---|---|---|---|
| | Number | Dimensions | Average | Range |
| Subsample: | | | | |
| Mossy logs | 3 | 2x4 inches | 4 | 1-11 |
| Boles, breast height | 2 | 6x12 inches | 75 | 2-282 |
| Boles, lower crown | 2 | 6x12 inches | 56 | 0-173 |
| Log stubs | 2 | 6-inch sections | 30 | 2-108 |
| Boles, midcrown | 2 | 6x12 inches | 52 | 1-194 |

## Favored Places for Egg Deposition

On the tree, eggs were found on mosses, on the undersides and edges of flat lichens, and under bark scales. Moss aggregations were usually associated with roughened, scaly bark, whereas lichens were present on smooth bark, usually high in the tree. Very few eggs were found on areas consisting only of bark scales. On ground sites, eggs were found chiefly on true mosses and only occasionally on clubmosses and liverworts. On all sites, true mosses were clearly preferred for egg deposition.

The association of egg deposition with moss indicated that the best expression of egg numbers for evaluation purposes would be on the basis of unit areas

of moss; i.e., 100 square inches. Distribution of eggs was interpreted on this basis and the term "egg density" applied. Since flat lichens were acceptable for egg deposition but usually occurred on the tree where mosses were absent, these were included with mosses to construct egg density.

The midcrown area had the greatest concentration of eggs on moss. Midcrown and upper-crown boles had similar egg densities; however, the actual number of eggs on upper-crown boles was small. Midcrown limbs had a higher egg density than limbs in the other two crown levels. Egg density on moss in the tree crown was generally higher than egg density on moss in ground locations. Data are shown in table 3.

Table 3.--Moss coverage and density of eggs on moss for subsamples removed from 12 western hemlock trees near Nemah, Wash., November-December 1962

| Subsample unit | Totals for all subsamples | | | | Eggs per 100 square inches of moss (average) |
|---|---|---|---|---|---|
| | Surface area of subsamples | Eggs | Surface area of moss | | |
| | Sq. in. | Number | Percent | Sq. in. | Number |
| Tree sites: | | | | | |
| Limbs: | | | | | |
| Lower crown | 2,371 | 899 | 67 | 1,589 | 57 |
| Midcrown | 2,053 | 1/1,006 | 48 | 985 | 102 |
| Upper crown | 1,458 | 164 | 13 | 189 | 87 |
| Boles: | | | | | |
| Lower crown | 1,728 | 667 | 34 | 587 | 114 |
| Midcrown | 1,728 | 627 | 22 | 380 | 165 |
| Upper crown | 1,728 | 211 | 7 | 121 | 174 |
| Breast height | 1,728 | 899 | 50 | 864 | 104 |
| Total | 12,794 | 4,473 | -- | 4,715 | -- |
| Average | -- | -- | -- | -- | 95 |
| Ground sites: | | | | | |
| Stubs on logs | 622 | 362 | 72 | 448 | 81 |
| Huckleberry stems | 525 | 362 | 78 | 410 | 88 |
| Mossy logs | 288 | 45 | 96 | 276 | 16 |
| Mossy ground | 288 | 44 | 89 | 256 | 17 |
| Total | 1,723 | 813 | -- | 1,390 | -- |
| Average | -- | -- | -- | -- | 58 |

1/ Three eggs on a subsample with no moss are omitted.

Vertical surfaces had higher egg densities than nearby horizontal surfaces, both within the crown and on ground locations. At each crown position, boles had about twice the egg density of limbs, even though moss coverage on boles was half that of limbs. On the ground, log stubs and huckleberry stems had about five times as many eggs per unit area of moss as did log surfaces and mossy ground. Moss coverage was slightly higher on the log and ground surfaces. Although moss was preferred for egg deposition, beyond a certain minimum area of coverage (approximately 20 percent) the actual amount had little bearing on the amount of egg deposition.

## Tree Site–Ground Site Relationships

Although the advantages of expressing density of eggs on a moss-area basis were apparent, the other two expressions (number of eggs on subsamples and number of eggs per unit area of subsample surface) were also used to test relationships graphically. In all cases, scatter was less when egg density on moss was used, even though most relationships were not statistically significant.

Use of a tree index (with eggs on moss) was enhanced when egg density on limbs was found correlated with that on boles. Separate analyses by crown position showed correlation at the 1-percent level between limbs and boles at both midcrown and upper crown. Correlation for the lower crown failed because of nonconforming estimates on one tree. Relationships are shown in figure 2.

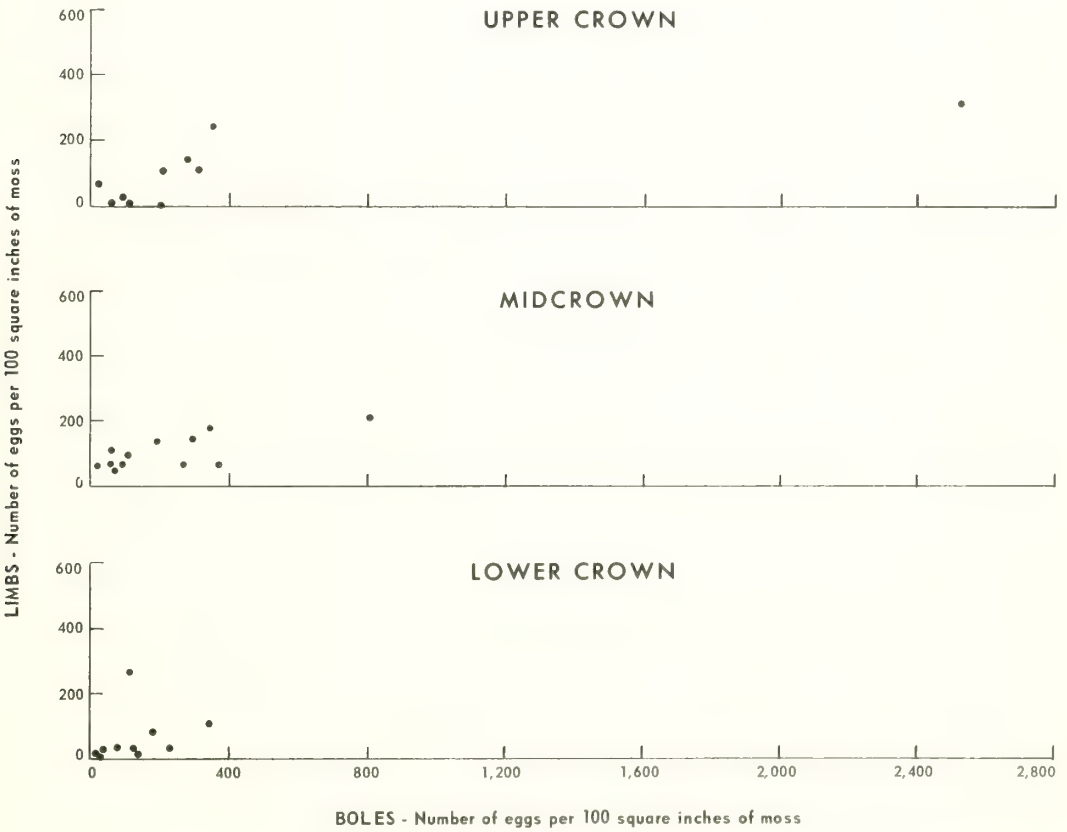


Figure 2. --Relationship between egg densities on limbs and boles of western hemlock.

No definite relationship was found between egg densities on tree sites and ground sites. None of the various ground-site or breast-high-bole samples could be correlated with the tree index, midcrown boles, or midcrown limbs. Egg densities on breast-high boles and various ground-site units were unrelated.

Two combinations of ground-site samples, having similar egg densities, were tested for correlation with the tree index. With mossy ground + mossy log surface, correlation was approached ($r = 0.516$) at the 5-percent level. With huckleberry stems + log stubs, no correlation was evident.

Comparison was made of mossy ground + mossy log surface with midcrown boles for relative efficiency in sampling. On the former, the mean egg density for 12 trees was $17.1 \pm 4.6$, the standard error being 27 percent of the mean. For confidence in this estimate ($P = 0.05$), approximately 50 trees should be sampled at a cost of 5.22 man-hours per tree for examination. On midcrown boles the mean was $233.6 \pm 80.6$, the standard error being 34.5 percent of the mean. For a standard error of 27 percent ($P = 0.05$), 73 paired bole samples should be taken at a cost of 2.2 man-hours per tree for examination plus 0.5 man-hour for felling the tree. Costs of using midcrown boles are 64 man-hours less than the mossy ground + log sample. This shows that, for evaluation purposes, felling trees is justified in order to get precise population estimates.

## DISCUSSION

In this study, estimates of man-hours were based on visual examination of subsample units. While it is likely that mechanical processing will reduce costs of examining most kinds of samples, the relative efficiency of the various samples will be mainly unchanged.

It is important that sampling for detection purposes be recognized as distinct from other kinds of sampling. Sampling techniques for detection are meant to show quickly and precisely whether appreciable infestation exists at a sample point or plot and to outline areas requiring evaluation surveys. Criteria, expressed as number of eggs found, vary with the choice of sampling unit. The egg counts obtained should not be construed as indices of the population levels on overstory trees.

Evaluation of egg populations on overstory trees can apparently be done only by felling trees. This creates a problem in attempting to establish standards for evaluation surveys, particularly in relating populations to subsequent damage. Further study of the mossy log + mossy ground combination is needed to determine whether or not larger samples will show a higher correlation with populations in trees and whether mechanical processing will reduce costs appreciably.

Physical obstacles in sampling inaccessible areas must be considered. In detection surveys, because of varying costs involved in hauling samples through the woods, some flexibility as to choice of sample units is advisable.

On the other hand, surveys to estimate population levels on overstory trees leave no alternative to the cutting of trees for sampling boles at midcrown.

## CONCLUSIONS

The best sampling units for detecting looper infestations, when visual examination is required, are mossy log surfaces and bole sections at breast height. Because numbers of eggs found on log surfaces are low, increasing the number of 2x4-inch subsamples might be desirable if method error is appreciable. Cost factors not considered in this study, such as that of transporting samples through the woods, might enhance the relative efficiency of log stubs.

Egg deposition is clearly associated with moss on roughened bark and with flat lichens on smooth bark; also, vertical surfaces have more eggs per unit area of moss than horizontal surfaces.

Egg density on moss is greatest on the bole in the upper and middle crown, followed by the bole in the lower crown and at breast height, limbs at midcrown, huckleberry stems, upper limbs, log stubs, and lower limbs. The midcrown area has the greatest concentration of eggs.

Correlations between egg densities on limbs and boles within the crown indicate that either may be used as an index of tree populations. Boles at midcrown are a logical choice, since density of eggs on moss is greater than on other samples and examination costs are low.

Estimating tree populations from ground-site samples is not shown feasible. While one combination of ground-site samples showed borderline correlation with tree populations, costs are greater than felling the tree and sampling midcrown boles.

Carolin, V. M., Johnson, N. E., Buffam, P. E., and McComb, D.
1964. Sampling egg populations of western hemlock looper in coastal forests. U.S. Forest Serv. Res. Paper PNW-14, 13 pp., illus.

Distribution of eggs on overstory trees and ground sites was studied in order to improve survey techniques in detecting and evaluating infestations. The best sampling units for detection were mossy log surfaces and breast-high bole sections. The best method for estimating populations on overstory trees was to fell the tree and sample the bole at midcrown.

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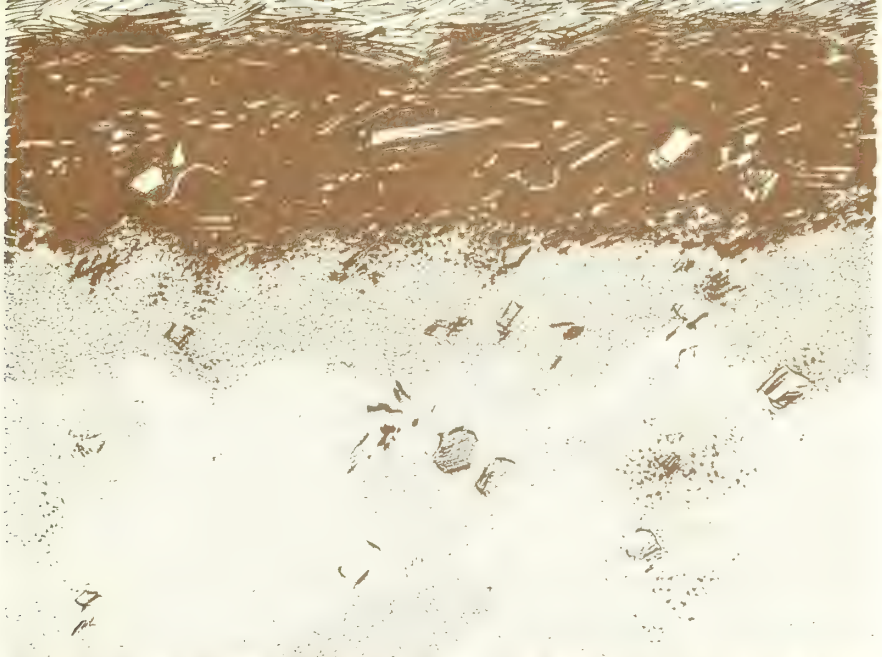

# FOREST SOILS RESEARCH in Oregon and Washington

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## in Oregon and Washington

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Robert F. Tarrant

October 1964

PACIFIC NORTHWEST
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Philip A. Briegleb, Director Portland, Oregon

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

# FOREWORD

The purpose of this paper is to reference and briefly summarize all published forest soils research done in Oregon and Washington--from observations by Hanzlik in 1914 to those made by a later generation of scientists through 1963.

Most forest soils research in the Pacific Northwest started after World War II when activity in this research field was accelerated. Of 139 references listed, only 11 were published before 1947. Thus, we have a unique opportunity in this subject matter area to summarize current status of published knowledge for handy reference.

Excellent publications on results of forest soils research are also available from regions adjacent to Oregon and Washington. Deciding where to draw a boundary as a basis for inclusion of references was difficult, however, especially when applicability of results was considered. We decided, therefore, to limit this summary to research done within the boundaries of only two States. Perhaps workers in other regions will find it profitable also to develop summaries of forest soils research for their areas.

We have attempted in the abstracts to accurately brief major findings or theme of each reference. This condensed information is intended only to lead the reader to the original publication for any study in which he may be especially interested.[1/] A subject matter index is also provided for the reader's convenience.

The author was assisted in this compilation by members of the Northwest Forest Soils Council. We will appreciate being notified of any omissions.

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[1/] Publications listed herein are not available from the Pacific Northwest Forest and Range Experiment Station unless issued by that organization. Requests for reprints should be addressed to the author cited.

# BIBLIOGRAPHY


1. Anonymous.
   1914. A study of the growth and yield of Douglas fir on various soil qualities in western Washington and Oregon, by E. J. Hanzlik. [A review.] Forestry Quart. 12: 440-441.

   Douglas-fir grows best on slopes rather than on level land, and good drainage is necessary. Best soils for Douglas-fir are medium to deep loams with sandy or gravelly subsoils; shallow loams or shallow sands with rock outcrops are poor. Douglas-fir often grows better on benchlands and hill soils than on bottom lands.

2. Anonymous.
   1952. Forest soils not depleted by timber harvest. Jour. Forestry 50: 872.

   Mineral elements removed from soil by trees are largely returned to the soil as leaf litter which soil organisms decompose into its original constituents for reuse. Because of the long time required to produce a tree crop, soil nutrient depletion is more than counterbalanced by weathering of soil minerals, addition of nitrogen by rainfall, and action of nitrogen-fixing soil organisms.

3. Anonymous.
   1956. Minimizing watershed disturbance from logging operations. Soc. Amer. Foresters Proc. 1955: 202-205.

   Eleven questions, most of which concerned soil disturbance after logging, were directed to a panel of foresters. Answers are given in detail.

4. Anderson, Henry W.
   1954. Suspended sediment discharge as related to streamflow, topography, soil, and land use. Amer. Geophys. Union Trans. 35: 268-281, illus.

   Includes (1) map of sediment-producing potential of lands in western Oregon under average land use; (2) estimate of how actual production of sediment would differ from the potential with deviation of land use from average; and (3) data on sediment production from forest land, agricultural land, and main river channel banks.

5. Arnold, John F.
   1963. The delineation of field stability hazards. In Forest Watershed Management Symposium. Oreg. State Univ., pp. 193-214, illus.

   Discusses principles involved in initial stratification of landscape features for extending experience with soil stability. Describes some factors involved in appraising forest soil stability.

6. Arnold, John F.
1963. Road location to retain maximum stability. In Forest Watershed Management Symposium. Oreg. State Univ., pp. 215-224, illus.

Discusses some basic principles in locating forest roads to prevent undue erosion of forest land.

7. Austin, R. C., and Baisinger, D. H.
1950. Manual for forest soils evaluation. Crown Zellerbach Corp., 24 pp., illus.

A compilation of information, in pocket form for field use, for typing forest soils to determine land value in terms of wood productivity.

8. _____ and Baisinger, D. H.
1955. Some effects of burning on forest soils of western Oregon and Washington. Jour. Forestry 53: 275-280, illus.

Measurable physical and chemical effects of fire were confined to the top 2 inches of soil. Two years after burning, organic matter, nitrogen, and available mineral elements had increased substantially over levels immediately after the fire. Three cases are described in which poor seedling growth was ascribed to soil deterioration after fire.

9. _____ and Strand, R. F.
1960. The use of slowly soluble fertilizers in forest planting in the Pacific Northwest. Jour. Forestry 58: 619-627, illus.

Reports results of fertilizer trials with commercial resin, DuPont Uramite, pelleted with superphosphate on plantations of Douglas-fir, grand fir, noble fir, Monterey pine, and a hybrid pine *(Pinus attenuata* X *radiata)* at four locations in Oregon and Washington. Height and diameter growth response varied with species and location. Possible interactions of site preparation, climate, species sensitivity to fertilizer, and time after fertilizing are discussed.

10. Banta, David.
1963. Maintaining soil stability in the design and construction of logging roads. In Forest Watershed Management Symposium. Oreg. State Univ., pp. 225-231.

Logging road design should include consideration of soil characteristics. Engineers and construction supervisors should correlate personal experience with knowledge of soil characteristics to more effectively maintain soil stability in areas affected by roadbuilding.

11. Bethlahmy, Nedavia.
1958. Forests and water yield. Amer. Soc. Civ. Engin. Proc. 84 (SA6, 1848): 1-5.

Forest environment can be manipulated to manage water resources, but soil impairment must be avoided.

12. _____
1960. Fertilizer helps establish grass seedings on abandoned logging roads. Jour. Forestry 58: 965-966, illus.

Heavy applications of fertilizer increase chances of establishing grass seedings on abandoned logging roads in the western part of the Cascade Range.

13. _____
1960. Surface runoff and erosion--related problems of timber harvesting. Jour. Soil & Water Conserv. 15(4): 158-161, illus.

A discussion of the effects of roads, logging methods, and controlled burning on surface runoff and erosion, and the role of research in solving these problems.

14. _____
1962. First year effects of timber removal on soil moisture. Internatl. Assoc. Sci. Hydrol. Bul. 7(2): 34-38, illus.

A study of undisturbed soils of clear cuts and adjacent nonlogged virgin forests in western Oregon indicated that clear cutting reduces soil moisture depletion and accelerates recharge.

15. _____
1963. Soil-moisture sampling variation as affected by vegetation and depth of sampling. Soil Sci. 95: 211-213.

Soil moisture variation is less under forest cover than in clear-cut areas and decreases in proportion to depth in the soil profile.

16. Bishop, Daniel M.
1961. Soil moisture depletion in three lodgepole pine stands in northeastern Oregon. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 213, 2 pp., illus.

Substantial amounts of soil moisture are consumed during the growing season in lodgepole pine stands of the Blue Mountains. Combined effects of evaporation and transpiration appear to account for a major part of the moisture depletion.

17. _____
1962. Lodgepole pine rooting habits in the Blue Mountains of northeastern Oregon. Ecology 43: 140-142, illus.

Lodgepole pine trees growing in basalt-pumice soils of the Blue Mountains develop distinct lateral and vertical root systems. Most roots

are in the highly permeable pumicite layer. Dense growth of rootlets on the lower taproot may be caused by nutrients and moisture stored in the residual basalt soil beneath pumicite.

18. Bollen, W. B., and Wright, Ernest.
1961. Microbes and nitrates in soils from virgin and young-growth forests. Canad. Jour. Microbiol. 7: 785-792.

Discusses distribution of *Penicillium*, *Mucor*, and *Aspergillus* spp. in forest soils and compares nitrate-nitrogen content in soil beneath several major forest tree species.

19. Carmean, Willard H.
1954. Site quality for Douglas-fir in southwestern Washington and its relationship to precipitation, elevation, and physical soil properties. Soil Sci. Soc. Amer. Proc. 18: 330-334, illus.

Douglas-fir site quality in southwestern Washington appears to be correlated with available soil moisture during the growing season. Site quality increased as soil depth and precipitation increased and decreased as gravel content, soil compaction, and elevation increased. The product of moisture equivalent times percent gravel was directly correlated with site quality.

20. _____
1956. Suggested modifications of the standard Douglas-fir site curves for certain soils in southwestern Washington. Forest Sci. 2: 242-250, illus.

Site curves for stands on soils derived from basalts, sandstones, and shales are similar to standard Douglas-fir site curves used in the Pacific Northwest. However, trees growing on gravels and sands and on soils with imperfect internal drainage have markedly different site curves. When stands are less than 100 years of age, the standard curves overestimate site quality on sands and gravels and underestimate site quality on imperfectly drained soils.

Modified site curves are presented for Douglas-fir established on gravels and on soils with imperfect internal drainage.

21. Cole, D. W., Gessel, S. P., and Held, E. E.
1961. Tension lysimeter studies of ion and moisture movement in glacial till and coral atoll soils. Soil Sci. Soc. Amer. Proc. 25: 321-325, illus.

Effectiveness of an alundum tension lysimeter was studied in two widely contrasting soils--one developed on glacial till in western Washington and another from a coral atoll of the northern Marshall Islands. The lysimeter is shown to be useful for measuring ion content of gravitational soil water. Amount of nutrient ion leaching is described for both soils.

22. Deardorff, C. E., and Lloyd, William J.
1958. Interpreting soil surveys for use in growing wood crops. First No. Amer. Forest Soils Conf. Proc. 1958: 213-217.

Three key soils with distinctly different suitabilities for wood crops are described in detail, and interpretations and conservation practice recommendations are made for each soil. The soil survey, with proper interpretation, is considered a logical and scientific base for managing forests in accordance with capabilities and limitations of the land.

23. Dimock, Edward J., II.
1958. Litter fall in a young stand of Douglas-fir. Northwest Sci. 32: 19-29, illus.

Over a 6-year period, litter fall decreased with increased intensity of thinning. Litter fall varies between years and between seasons within 1 year. Extreme low temperatures may triple amount of litter that falls the ensuing year.

24. Dunford, E. G.
1956. A watershed research program for the Pacific Northwest. Soc. Amer. Foresters Proc. 1955: 190-195.

Soils aspects of a proposed watershed research program include studies designed to help control disturbance and movement of forest soils in logging and other management operations. A major line of investigation is to determine physical characteristics and management requirements of important soil types in forest and range watersheds of the Pacific Northwest.

25. _____
1958. Forest soils--enigma of Northwest watersheds. First No. Amer. Forest Soils Conf. Proc. 1958: 20-24.

Discusses general characteristics of soil; geology and climate of the Pacific Northwest; land uses affecting soils; effects of roadbuilding, logging, and fire on watershed soils; and future trends in research.

26. _____
1958. Watershed management research in the Pacific Northwest. Jour. Soil & Water Conserv. 13(1): 23-26.

A summary of problems and description of an active research program including studies of soil erosion and stability in relation to logging and roadbuilding, erosion hazard, and rehabilitation of eroded lands.

27. _____
1960. Watershed management research in the Lake States, Intermountain, and Pacific Northwest Regions. Jour. Forestry 58: 288-290.

A summary of soil and water investigations by research organizations on forest and range lands.

28. Dunford, Earl G.
1962. Logging methods in relation to streamflow and erosion. Fifth World Forestry Cong. Proc. 3: 1703-1708.

Reviews status of knowledge about influence of logging and road-building on forest soil erosion. Lists recommendations for minimizing erosion and stream damage during and following logging operations.

29. Dyrness, C. T.
1963. Effects of burning on soil. In Forest Watershed Management Symposium. Oreg. State Univ., pp. 291-304.

Summarizes available information with particular reference to studies of slash burning in the Douglas-fir region.

30. _____ and Youngberg, C. T.
1957. The effect of logging and slash-burning on soil structure. Soil Sci. Soc. Amer. Proc. 21: 444-447, illus.

Soil structure was damaged only where soil was severely burned, but only 8 percent of the soil surface was in this category. Thus, high-lead logging and burning slash in the fall after a rain had no appreciable detrimental effect on soil structure over the area as a whole.

31. _____ and Youngberg, C. T.
1958. Soil-vegetation relationships in the central Oregon pumice region. First No. Amer. Forest Soils Conf. Proc. 1958: 57-66.

Describes soil-vegetation relationships under lodgepole and ponderosa pine and under ponderosa pine associated with bitterbrush, manzanita, snowbrush, and Idaho fescue. Discusses profile variability in the Lapine soil series, explains features of well-drained and poorly drained soils, and suggests application of soil-vegetation information to forest management practices.

32. _____ Youngberg, C. T., and Ruth, Robert H.
1957. Some effects of logging and slash burning on physical soil properties in the Corvallis watershed. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 19, 15 pp., illus.

Soil structure was damaged only where soil was severely burned, but only 8 percent of the soil surface was in this category. Thus, high-lead logging and burning slash in the fall after a rain had no appreciable detrimental effect on soil structure over the area as a whole.

33. Enberg, Paul.
1963. Design of roadway drainage to prevent erosion on forested watersheds. In Forest Watershed Management Symposium. Oreg. State Univ., pp. 233-251, illus.

Factors influencing road drainage design and steps in designing road drainage systems are described.

34. Erickson, Harvey D., and Lambert, Gregory M. G.
1958. Effects of fertilization and thinning on chemical composition, growth, and specific gravity of young Douglas-fir. Forest Sci. 4: 307-315.

Little difference in wood quality was noted between trees from various fertilizer and thinning treatments. Growth rate, in descending order by treatment, was: fertilized and thinned, fertilized, thinned, and untreated. Percent of summerwood decreased significantly after thinning and fertilizing. The increased volume increment obtained by fertilizing and thinning had much more fiber than wood of the same age in untreated stands.

35. Flannery, Robert D.
1940. Physical character and chemical composition of forest floors under selected forest types in western Washington. [Abs.] Ecol. Soc. Amer. Bul. 21: 11.

Litter of forest trees maintains a high base content in the forest floor, which perhaps explains why podsolization proceeds very slowly in northwestern Washington.

36. Forest Soils Committee of the Douglas-fir Region.
1953. Sampling procedures and methods of analysis for forest soils. 38 pp., illus. Seattle: Univ. Wash.

Methods of sampling and detailed procedures for physical and chemical analysis of forest soils are given in an attempt to standardize results.

37. _____
1957. An introduction to the forest soils of the Douglas-fir region of the Pacific Northwest. Various paging, illus. Seattle: Univ. Wash.

Provides some essential regional forest soils information, points out some common soils problems and soil-plant interrelationships, and explains fundamentals of forest soils in terms of those found in the Douglas-fir region.

38. Forristall, Floyd F., and Gessel, S. P.
1955. Soil properties related to forest cover type and productivity on the Lee Forest, Snohomish County, Washington. Soil Sci. Soc. Amer. Proc. 19: 384-389, illus.

Depth to hardpan layer was important for rating soil productivity for tree growth. Poor soil drainage appeared to be the dominating influence on forest type.

39. Fowells, H. A., and Stephenson, R. E.
1934. The effect of burning on forest soils. Soil Sci. 38: 175-181.

Temporarily stimulating nitrification and increasing soluble mineral nutrients in the soil by burning may be helpful in some respects. However, forest soil productivity depends upon gradual mineralization of fallen litter, so continuous and often repeated burning cannot be expected to improve fertility.

40. Fredriksen, R. L.
1963. A case history of a mud and rock slide on an experimental watershed. Pac. NW. Forest & Range Expt. Sta. U.S. Forest Serv. Res. Note PNW-1, 4 pp., illus.

Description of a landslide typical of many which occur during winter storms in steep forest lands of the Pacific Northwest.

41. Garrison, George A., and Rummell, Robert S.
1951. First-year effects of logging on ponderosa pine forest range lands of Oregon and Washington. Jour. Forestry 49: 708-713, illus.

Tractor logging removed more herbaceous and shrubby vegetation and covered more of the logged area with slash than did cable logging. Horse logging was least damaging to vegetation. Soil was deeply disturbed on 15 percent of the tractor-logged area. In contrast, only 2 percent of cable- and horse-logged areas was thus affected. Reductions in quantity and quality of grasses damaged grazing values.

42. Gehrke, F.
1963. Forest soil surveys--methods, status, resulting information and use in management. In Forest Watershed Management Symposium. Oreg. State Univ., pp. 179-191.

43. Gessel, S. P.
1959. Forest soil fertility problems and research in the western United States. Soc. Amer. Foresters Proc. 1958: 177-180.

Fertilizers have potential value in increasing forest growth. Inventories of forest soils, basic tree nutrition studies, and field testing are needed to further the use of fertilizer in the forest industry.

44. _____ and Abdullah, Shareeff.
1957. Response of 30-year-old Douglas-fir to fertilization. Soil Sci. Soc. Amer. Proc. 21: 236-239, illus.

Application of nitrogen fertilizer plus small amounts of phosphorus, potassium, and lime accelerated diameter and volume growth. Small trees were more rapidly suppressed. The 50 largest trees on the fertilized plot had about the same periodic annual increment as the total stand on the plot without fertilizer.

45. _____ and Cole, D. W.
1958. Physical analysis of forest soils. First No. Amer. Forest Soils Conf. Proc. 1958: 42-48, illus.

Points out need for data on important soil physical properties and summarizes latest methodology.

46. _____ and Walker, R. B.
1958. Diagnosing nutrient needs of forest trees. Better Crops with Plant Food 42(8): 26-31, 34-38, illus. (Also, in Forest Fertilization, pp. 20-27, 30-31, illus. 1958.)

Carefully standardized foliage analysis is useful in diagnosing nutrient needs of forest trees. Results of foliage analysis can be interpreted in terms of nutrient needs for maximum tree growth. Soil tests are more valuable if standard procedures are used and resulting data are related to foliage nutrient information.

47. _____ and Walker, R. B.
1958. On growing forest trees. Plant Food Rev. 4: 17-20, 29.

Discusses the place of fertilizer in management of forest resources in the Pacific Northwest.

48. Gessel, Stanley P.
1948. Soil science and the forester. Univ. Wash. Forest Club Quart. 22(3): 3-12.

Describes the importance of forest soils information to forest managers and the need for increased research effort.

49. _____
1949. Correlation between certain soil characteristics and site for Douglas-fir in northwestern Washington. Soil Sci. Soc. Amer. Proc. 14: 333-337, illus.

Productivity of land for Douglas-fir growth was predicted from soil characteristics. Texture and depth were especially influential. Within a single soil unit, site index was related to mean annual precipitation.

50. Gessel, Stanley P.
1962. Progress and problems in mineral nutrition of forest trees. In Tree Growth. Theodore T. Kozlowski, ed., pp. 221-235, illus. New York: The Ronald Press Co.

Summarizes, with special emphasis on Pacific Northwest research.

51. _____ and Lloyd, William J.
1950. Effect of some physical soil properties on Douglas-fir site quality. Jour. Forestry 48: 405-410, illus.

Productivity of land for Douglas-fir growth was predicted from soil characteristics. Texture and depth were especially influential. Within a single soil unit, site index was related to mean annual precipitation.

52. _____ Turnbull, Kenneth J., and Tremblay, F. Todd.
1960. How to fertilize trees and measure response. Natl. Plant Food Inst., 67 pp., illus.

Tells how to (1) fertilize soil to increase tree growth, (2) measure trees, and (3) evaluate growth rates after soil treatment.

53. _____ and Walker, Richard B.
1956. Height growth response of Douglas fir to nitrogen fertilization. Soil Sci. Soc. Amer. Proc. 20: 97-100, illus.

Nitrogen fertilizer increased height growth of 15- to 20-year-old Douglas-fir on poor sites in western Washington. Large trees responded to fertilizer more than smaller ones. Foliage color was darker green when fertilizer was used. The latter finding is discussed as it relates to Christmas tree production.

54. _____ Walker, Richard B., and Haddock, Philip G.
1950. Preliminary report on mineral deficiencies in Douglas-fir and western red cedar. Soil Sci. Soc. Amer. Proc. 15: 364-369, illus.

Douglas-fir and western redcedar require nitrogen, phosphorus, and potassium for good growth. Nitrogen is especially important. Western redcedar foliage contains more calcium than that of Douglas-fir.

55. Gilkeson, R. H., Starr, Warren A., and Steinbrenner, E. C.
1961. Soil survey of the Snoqualmie Falls Tree Farm. 10 pp., 14 maps. Weyerhaeuser Co. and Wash. Agr. Expt. Sta. cooperative publication.

Presents results of the first soil survey of an industrial tree farm in the Pacific Northwest.

56. Hale, Charles E.
1950. Some observations on soil freezing in forest and range lands of the Pacific Northwest. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 66, 17 pp., illus.

Under normal winter and early spring conditions, soil freezing occurs in all soil-cover complexes of eastern Oregon. Because of discontinuity and limited duration of impermeable frost, however, effect of frost on snowmelt runoff under average conditions appears unimportant in hydrologic considerations.

57. _____
1951. Further observations on soil freezing in the Pacific Northwest. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 74, 8 pp., illus.

Under normal winter and early spring conditions, soil freezing occurs in all soil-cover complexes of eastern Oregon. Because of discontinuity and limited duration of impermeable frost, however, effect of frost on snowmelt runoff under average conditions appears unimportant in hydrologic considerations.

58. Hayes, G. L.
1952. Soil texture can influence forest regeneration from seed. U.S. Forest Serv. Tree Planters' Notes 11: 2.

Thirty-eight percent of Douglas-fir seed placed in a sandy loam soil produced seedlings compared with only 18 percent for those placed in pumice. Cutover tracts on fine-textured soils might thus have a better chance of regenerating naturally or from direct seeding than those on coarse pumice. Planting may be surer on pumice soils.

59. Heilman, Paul E., and Gessel, S. P.
1963. The effect of nitrogen fertilization on the concentration and weight of nitrogen, phosphorus, and potassium in Douglas-fir trees. Soil Sci. Soc. Amer. Proc. 27: 102-105, illus.

Almost twice as much nitrogen, greater quantities of potassium, and approximately equal amounts of phosphorus were contained in vegetation on fertilized plots as were contained in unfertilized vegetation. Douglas-fir needles increased in nitrogen more than branches and bark while wood did not increase.

60. _____ and Gessel, S. P.
1963. Nitrogen requirements and the biological cycling of nitrogen in Douglas-fir stands in relationship to the effects of nitrogen fertilization. Plant & Soil 18: 386-402, illus.

Minimum nitrogen requirement for adequate growth of Douglas-fir is estimated at about 4,000 pounds per acre in soil and forest floor combined. Nitrogen fertilizer had a lasting effect on growth and nutrition of nitrogen-deficient Douglas-fir.

61. Hermann, Richard K.
1962. Root development and height increment of young ponderosa pine in pumice soils in central Oregon. (Abs.) Ecol. Soc. Amer. Bul. 43: 76.

Growth of 20- to 70-year-old ponderosa pine 12 to 15 feet tall was extremely slow until roots had penetrated the C horizon of nearly unweathered pumice. After roots reached the buried soil beneath pumice, however, height increment increased 50 to 150 percent. Tree growth was not related to chemical characteristics of the soil.

62. _____
1963. Temperatures beneath various seedbeds on a clearcut forest area in the Oregon Coast Range. Northwest Sci. 37: 93-103, illus.

Organic soil surfaces create a more severe microclimate above ground than do mineral surfaces. At a depth of 1 inch below organic surfaces, however, maximum temperatures averaged from 10° to 20° lower than those beneath mineral surfaces. Temperatures beneath mineral surfaces were not only higher than under organic surfaces but also persisted for a longer time.

63. Hill, W. W., Arnst, Albert, and Bond, R. M.
1948. Method of correlating soils with Douglas-fir site quality. Jour. Forestry 46: 835-841, illus.

Douglas-fir site quality appears to be related to soil moisture relationships. Within a given soil type, site index increases as precipitation increases.

64. Holtby, B. E.
1947. Soil texture as a site indicator in the ponderosa pine stands of southeastern Washington. Jour. Forestry 45: 824-825, illus.

Soil texture 6 inches below the surface was a fairly reliable indicator of site quality.

65. Isaac, Leo A., and Hopkins, Howard G.
1937. The forest soil of the Douglas fir region, and changes wrought upon it by logging and slash burning. Ecology 18: 264-279.

Authors conclude that damage to forest soil by slash burning is roughly proportional to the completeness with which fire consumes surface organic matter.

66. Lemmon, Paul E.
1955. Factors affecting productivity of some lands in the Willamette Basin of Oregon for Douglas-fir timber. Jour. Forestry 53: 323-330, illus.

Total effective soil depth was the most important factor in determining productive capacity of a site for Douglas-fir. This factor appears to gain its importance through internal water relationships of the soil profile.

67. _____ Johnson, Roy A., and Krauter, Orlo W.
1955. Site index curves for lodgepole pine in the pumice area of central Oregon. Jour. Forestry 53: 553-555, illus.

Presents growth curve, site index table, and site index curves for lodgepole pine measured in natural, unmanaged stands on pumice soils in central Oregon. A method is suggested for adjusting U.S. and B.C. Forest Services' yield tables to use in central Oregon.

68. Lloyd, W. J., Schlots, F. E., and Deardorff, C. E.
1956. Forest management practices as related to and influenced by forest soil differences in western Washington. Soil Sci. Soc. Amer. Proc. 20: 105-107, illus.

Forest growth patterns are described for different soils. Specific forest management recommendations are given to illustrate fitting management to individual soils.

69. Lowry, G. L., and Youngberg, C. T.
1955. The effect of certain site and soil factors on the establishment of Douglas-fir on the Tillamook burn. Soil Sci. Soc. Amer. Proc. 19: 378-380, illus.

Aspect, slope steepness, and soil texture appeared to influence Douglas-fir seedling survival. Lowest seedling survival was on coarse-textured soils on slopes of more than 40 percent with a southerly aspect. Highest survival was on loam or silt loam where slope was less than 40 percent with a northerly aspect. Where mortality was high, soils had been depleted of available moisture for about 30 days.

70. Mader, Donald L.
1953. Physical and chemical characteristics of the major types of forest humus found in the United States and Canada. Soil Sci. Soc. Amer. Proc. 17: 155-158.

Presents data for humus layer samples from the Pacific Northwest, including a duff mull and a matted mor from Douglas-fir—western hemlock stands and a medium mull from beneath a Sitka spruce forest.

71. Mosher, Milton M.
1960. Irrigation and fertilization of ponderosa pine. Wash. Agr. Expt. Sta. Cir. 365, 5 pp.

Irrigation and fertilizer applications at the rate of 200 pounds ammonium nitrate (33.3 percent N) per acre in a 90-year-old stand of ponderosa pine in northeastern Washington produced these increases in diameter growth compared with controls:

| Treatment | Percent increase |
|---|---|
| Once irrigated, nonfertilized | 76 |
| Twice irrigated, nonfertilized | 139 |
| Once irrigated, fertilized | 127 |
| Twice irrigated, fertilized | 94 |
| Nonirrigated, fertilized | 29 |

72. McKeever, D. G.
1946. Forest site evaluation: its importance to the forest products industries. Soil Sci. Soc. Amer. Proc. 11: 511-513.

Discusses importance of soil as it affects tree growth and needs of the forest industry for better soil-site information.

73. McKell, Cyrus M., and Finnis, J. M.
1957. Control of soil moisture depletion through use of 2,4-D on a mustard nurse crop during Douglas-fir seedling establishment. Forest Sci. 3: 329-335, illus.

A nurse crop of mustard *(Brassica nigra)* can reduce high soil temperatures during Douglas-fir seedling establishment. Soil moisture depletion by the nurse crop can be reduced by spraying with 2,4-D during full bloom. Leaves, retained for some time after plant death, shade seedlings.

74. Plair, T. B.
1950. The work of the Forest-Soils Committee of the Douglas-fir Region. Jour. Forestry 48: 95-96.

Primary objectives of the Forest Soils Committee of the Douglas-fir Region (now the Northwest Forest Soils Council), formed in 1948, are to (1) promote thought and discussion of forest soils, (2) suggest problems for study by research workers, and (3) serve as a focal point for the collection and dissemination of forest soils information.

75. Powers, W. L.
1932. Characteristics of forest soils of the northwestern United States. Soil Sci. 34: 1-10.

Organic matter of Northwest forest soils is in many stages of decomposition and contains different amounts of mineral soil material. Maximum water vapor absorption and numbers of microbes were found in fermenting layers. Maximum base exchange capacity was in neutral fermenting layers containing approximately 75 percent organic matter. Feeding roots of trees were concentrated in the forest soil just below this layer.

76. _____ and Bollen, W. B.
1935. The chemical and biological nature of certain forest soils. Soil Sci. 40: 321-328.

The nutrient-supplying power of forest soils, especially for bases and nitrates, is centered in the F and H layers. Micro-organisms and macro-organisms are important in humus-nitrogen generation.

77. Sartz, R. S.
1953. Soil erosion on a fire-denuded forest area in the Douglas-fir region. Jour. Soil & Water Conserv. 8: 279-281, illus.

Raindrop splash, which left little visible evidence, caused erosion after wildfire. Thus, erosion on fire-denuded forest lands may be more common than generally believed.

78. Sartz, Richard S.
1951. The October floods in southwestern Oregon--some observations and speculations. Jour. Forestry 49: 189-191, illus.

Many logged areas showed no accelerated erosion after abnormally high rainfall, but most skidroads, dirt access roads, drainage ditches, and cut and fill slopes did erode. Suggested remedies for control of such erosion are well-planned roads with adequate drainage facilities, stabilization of cut and fill slopes by mulching or seeding, obliteration and herbaceous seeding of skidtrails, and restriction of travel on woods roads during periods of high rainfall.

79. Schlots, F. E., Lloyd, W. J., and Deardorff, C. E.
1956. Some soil characteristics which affect root penetration and timber site quality of Douglas fir in western Washington. Soil Sci. Soc. Amer. Proc. 20: 101-105.

Slope, aspect, position on slope, and landform are important environmental factors which influence forest regeneration, management, and logging practices. Site quality is influenced most strongly by a combination of soil properties used to determine soil type.

80. Starr, Warren A.
1956. Soils information for use of the managing forester. Soc. Amer. Foresters Proc. 1955: 85-89.

Discusses kinds of soil and topography information needed for forest management planning, methods of reporting such information, and how it can be used by the forester.

81. Starr, Warren A., and Tarrant, Robert F.
1955. Evaluating and mapping mountain land features for forest management purposes. Wash. Agr. Expt. Sta. Cir. 271, 22 pp., illus.

Reports a method of appraising and mapping geology, soil, and topographic conditions which bear on National Forest land management in the State of Washington.

82. Steinbrenner, E. C.
1955. The effect of repeated tractor trips on the physical properties of forest soils. Northwest Sci. 29: 155-159, illus.

Under dry soil conditions, four trips with an HD 20 tractor reduced macroscopic pore space by half and infiltration rate by over 80 percent. Effects from one tractor trip on moist soil equaled four trips when soil was dry.

83. _____
1959. A portable air permeameter for forest soils. Soil Sci. Soc. Amer. Proc. 23: 478-481, illus.

The permeameter consists of a steel cylinder with carrying harness, constant pressure regulator, toggle-valve, soil tube, and pressure gauge. The tube is inserted into soil, a constant air pressure is delivered, and resistance of the soil to this pressure is read on the gauge as "percent macroscopic pore space." Application of this instrument to soil productivity studies is discussed.

84. _____
1961. Ten years of forest soils research in retrospect and prospect. Weyerhaeuser Co. Bul., 18 pp.

A review of the past 10 years' work in forest soils research by the Weyerhaeuser Co. and a brief description of research proposed for the next 10 years.

85. _____ Duffield, J. W., and Campbell, R. K.
1960. Increased cone production of young Douglas-fir following nitrogen and phosphorus fertilization. Jour. Forestry 58: 105-110, illus.

Greatest increase in tree growth and cone production was associated with nitrogen fertilizer treatments, although lesser increases occurred when phosphorus was applied together with a high rate of nitrogen.

86. _____ and Gessel, S. P.
1955. The effect of tractor logging on physical properties of some forest soils in southwestern Washington. Soil Sci. Soc. Amer. Proc. 19: 372-376.

Compared with an undisturbed timber area, soils affected by tractor logging had 35 percent less permeability, 2 percent greater bulk density, and 10 percent less macroscopic pore space. In tractor roads, permeability was reduced by 93 percent, bulk density was increased by 15 percent, and macroscopic pore space was reduced by 53 percent. Total area occupied by tractor roads was 26 percent of the cutting unit.

87. _____ and Gessel, S. P.
1956. Effect of tractor logging on soils and regeneration in the Douglas-fir region of southwestern Washington. Soc. Amer. Foresters Proc. 1955: 77-80, illus.

Tractor logging can seriously disturb soil through puddling, displacement, and compaction on skidroads. Soil compaction on skidroads, which cover 26 percent of the area logged by tractors, reduces stocking by nearly 50 percent and the number of established seedlings by two-thirds when compared with off-road conditions. Seedlings on roads were of poorer quality and showed less height growth the first 2 years than those planted off roads. In general, skidroads were poor growing sites for conifer seedlings.

88. _____ and Gessel, S. P.
1956. Windthrow along cutlines in relation to physiography on the McDonald Tree Farm. Weyerhaeuser Timber Co. Forestry Res. Notes, 19 pp., illus.

To lessen windthrow of Douglas-fir along cutlines, do not place cutting boundaries on the upper one-third of lee slopes, especially on or near saddles or ridges. Neither should cutlines be on shallow ridgetop soils or in poorly drained depressions. Avoid disturbing root systems, especially those of downhill buttressing roots, during salvage or roadbuilding operations.

89. Steinbrenner, Eugene C.
1953. Mustard seeding on burned forest areas. Weyerhaeuser Timber Co. Forestry Bul., 2 pp.

Mustard *(Bressica nigra)* was hand-seeded on a burned site to study its effect in controlling soil erosion. Natural forest vegetation which developed after the fire was as effective as seeded mustard in stabilizing soil and also prevented the mustard from reseeding the second year except where soil was disturbed.

90. Tarrant, R. F.
1947. First forest soil survey gives significant results. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 36, 4 pp.

In the Pringle Falls area of central Oregon, poorly drained soils generally support lodgepole pine but not ponderosa pine. Restricted air drainage, lower temperatures, more soil freezing, or frost damage in poorly drained soil areas may affect species distribution. The theory that competition after fire causes the present distribution pattern of the two species is questioned.

91. Tarrant, Robert F.
1947. A guide for forest soil examination in the Douglas-fir region. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 32 pp., illus. [Rev. 1950.]

Outlines some procedures used for examining and judging soil conditions.

92. _____
1948. The role of organic matter as a source of nitrogen in Douglas-fir forest soils. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 48, 4 pp., illus.

Regression analysis of total nitrogen and organic matter for 102 forest soil samples showed a close relationship between these two important soil properties. Most of the organic matter and nitrogen was in the uppermost soil layers.

93. _____
1949. Douglas-fir site quality and soil fertility. Jour. Forestry 47: 716-720.

No relation was found between Douglas-fir site class and pH, silt-plus-clay content, total nitrogen, available phosphorus and potassium, base exchange capacity, replaceable calcium and magnesium, or organic matter.

94. _____
1949. A program of forest soils research for the Pacific Northwest. Northwest Sci. 23: 64-71.

Outlines status of forest soils research in the Pacific Northwest as of 1948, and proposes a program of research. Proposals center about soil in relation to forest productivity, regeneration, and watershed management.

95. _____
1950. A preplanting forest soil survey. Jour. Forestry 48: 104-105.

A method of broadly evaluating productivity of land for planted Douglas-fir was based on a rating index which considered soil depth, texture, consistence, and organic matter content, plus slope and aspect.

96. _____ 1950. A relation between topography and Douglas-fir site quality. Jour. Forestry 48: 723-724.

On two different soil types, Douglas-fir site index was significantly higher for trees on concave rather than convex topography. Inclusion of a measure of topographic conditions is recommended for future forest soil surveys.

97. _____ 1953. Effect of heat on soil color and pH of two forest soils. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 90, 5 pp.

Soil color may roughly indicate intensity of a slash fire but cannot be used as a precise measure. Greatest change in soil pH results from burning temperatures below 900° F.

98. _____ 1953. Soil moisture and the distribution of lodgepole and ponderosa pine. (A review of the literature.) U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 8, 10 pp.

A review of literature on lodgepole and ponderosa pine occurrence as influenced by soil moisture conditions. Consensus is that lodgepole pine occurs on more moist sites than does ponderosa pine.

99. _____ 1954. Effect of slash burning on soil pH. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 102, 5 pp.

Significant differences in soil pH were found between unburned and light burn, unburned and severe burn, and light and severe burn soil conditions. Soil reaction decreased significantly with an increase in time since burning. This decrease is related to severity of the burn. No significant pH differences were found between unburned soil in a clear cut and unburned-undisturbed soil in adjacent timber.

Intensity of burning is not uniform over a clear-cut area, nor is the entire area directly affected by the fire.

100. _____ 1954. Soil reaction and germination of Douglas-fir seed. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 105, 4 pp., illus.

Three independent tests indicated there was no relation between soil reaction to a maximum of pH 9.7 and germination of Douglas-fir seed.

Thus, high pH within limits found after slash burning apparently would not prevent germination of Douglas-fir seed.

101. Tarrant, Robert F.
1956. Changes in some physical soil properties after a prescribed burn in young ponderosa pine. Jour. Forestry 54: 439-441, illus.

Under conditions of soil, topography, weather, and fuels studied, prescribed burning did not harm and may have improved slightly the permeability and associated physical properties of the soil.

102. _____
1956. Effect of slash burning on some physical soil properties. Forest Sci. 2: 18-22, illus.

Severe burning greatly lowered rate of moisture movement in two soils. Light burning did not hamper movement of water within the surface 3 inches of soil, although macroscopic pore space was reduced. Severe burn occurred only in small, scattered patches that, combined, amounted to only a small portion of the total surface of slash-burned areas. Thus, overall influence of slash burning on soil moisture properties was minor.

103. _____
1956. Effects of slash burning on some soils of the Douglas-fir region. Soil Sci. Soc. Amer. Proc. 20: 408-411, illus.

Effects of slash burning vary with different soils. Although severe burning damages some soil properties, total soil area thus affected represents only a small portion of the total area logged and burned. In weighing effects of slash burning on soil, consideration must be given to relative amounts of lightly burned, severely burned, and unburned soil surface.

104. _____
1956. Forest soils of the Pacific Northwest. Soc. Amer. Foresters Proc. 1955: 73-76, illus.

Discusses soil characteristics of the Coast Ranges, glaciated areas, eastern and western slopes of the Cascade Range, Siskiyou Mountains, and Blue-Wallowa Mountains of the Pacific Northwest. Extreme complexity of climate and geology within these broad physiographic subregions creates a diverse pattern of forest soils.

105. _____
1957. Soil moisture conditions after chemically killing manzanita brush in central Oregon. U.S. Forest Serv. Pac. NW.

Forest & Range Expt. Sta. Res. Note 156, 4 pp., illus. (Also, in Tree Planters' Notes 33: 12-14, illus. 1958.)

Beneath green brush, percent moisture at the 12-inch depth declined more than twice that of nonvegetated plots. At the 24-inch depth, moisture decline under green brush was almost three times that of nonvegetated plots.

106. _____
1961. Stand development and soil fertility in a Douglas-fir--red alder plantation. Forest Sci. 7: 238-246, illus.

Admixture of red alder in a Douglas-fir plantation increased growth of dominant firs. Total nitrogen, both in soil and Douglas-fir foliage, was significantly greater in the alder-fir plantation than in adjacent pure fir.

107. _____ Isaac, Leo A., and Chandler, Robert F., Jr.
1951. Observations on litter fall and foliage nutrient content of some Pacific Northwest tree species. Jour. Forestry 49: 914-915.

Red alder foliage contained nearly three times the amount of nitrogen as the average of 11 other species. Foliage phosphorus content was relatively low for all species. The only two broad-leaved trees studied, bigleaf maple and red alder, contained high amounts of potassium compared with conifers. Western redcedar and bigleaf maple were the only species whose foliage contained more than 1 percent calcium.

108. _____ and Miller, Richard E.
1963. Accumulation of organic matter and soil nitrogen beneath a plantation of red alder and Douglas-fir. Soil Sci. Soc. Amer. Proc. 27: 231-234.

Beneath a plantation of red alder and Douglas-fir, soil nitrogen and organic matter were greater and bulk density and carbon-nitrogen ratio were less than in an adjacent pure fir plantation of the same age. An average of 36 pounds per acre more soil nitrogen has accumulated each year beneath the mixed stand than under pure fir.

109. _____ and Wright, E.
1955. Growth of Douglas-fir seedlings after slash burning. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 115, 3 pp., illus.

Growth of planted Douglas-fir seedlings was not inhibited by previous slash burning.

110. Trappe, James M.
1957. Some probable mycorrhizal associations in the Pacific Northwest. Northwest Sci. 31: 183-185.

The technique of tracing hyphae through the soil from sporocarps to mycorrhizae is uncertain when used alone. However, it may be combined with knowledge of the fungi known to form mycorrhizae and of the obligativity of some fungi to certain tree species to identify associations considered very probably mycorrhizal.

111. _____
1960. Some probable mycorrhizal associations in the Pacific Northwest. II. Northwest Sci. 34: 113-117.

The technique of tracing hyphae through the soil from sporocarps to mycorrhizae is uncertain when used alone. However, it may be combined with knowledge of the fungi known to form mycorrhizae and of the obligativity of some fungi to certain tree species to identify associations considered very probably mycorrhizal.

112. _____
1961. Some probable mycorrhizal associations in the Pacific Northwest. III. Northwest Sci. 35: 91-94.

The technique of tracing hyphae through the soil from sporocarps to mycorrhizae is uncertain when used alone. However, it may be combined with knowledge of the fungi known to form mycorrhizae and of the obligativity of some fungi to certain tree species to identify associations considered very probably mycorrhizal.

113. _____
1962. Fungus associates of ectotrophic mycorrhizae. Bot. Rev. 28: 538-606.

A review of the limited literature comparing effects of different mycorrhizal fungi on their host; examines mycorrhizal associations from the standpoint of fungal taxonomic relationships; and presents new, updated lists of reported fungus-host associations.

114. _____
1963. Some probable mycorrhizal associations in the Pacific Northwest. IV. Northwest Sci. 37: 39-43.

The technique of tracing hyphae through the soil from sporocarps to mycorrhizae is uncertain when used alone. However, it may be combined with knowledge of the fungi known to form mycorrhizae and of the obligativity of some fungi to certain tree species to identify associations considered very probably mycorrhizal.

115. _____ and Harris, Robert W.
1958. Lodgepole pine in the Blue Mountains of northeastern Oregon. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 30, 22 pp., illus.

A study aimed at understanding better the establishment, development, and characteristics of lodgepole pine stands in the Blue Mountains. Describes limitations of lodgepole pine to certain soils.

116. Vandecaveye, S. C., and Baker, G. O.
1938. Microbial activities in soil: III. Activity of specific groups of microbes in different soils. Soil Sci. 45: 315-333, illus.

A forest soil was compared with an agricultural soil to study relative rate of decomposition of different kinds of plant residues and their influence on microbial activity. Total number of microbes was about five times as great in the agricultural soil. Microflora differed greatly in kind between the two soils. Microbial activity in both soils was increased greatly by adding 1 percent wheat straw and sweetclover hay. Adding 1 percent pine needles and coniferous forest litter to agricultural soil also increased microbial activity.

117. Walker, R. B., Gessel, S. P., and Haddock, P. G.
1955. Greenhouse studies in mineral requirements of conifers: western red cedar. Forest Sci. 1: 51-60, illus.

Greenhouse study of western redcedar seedlings showed response to nitrogen and phosphorus fertilizer. Characteristic deficiency symptoms developed in plants deprived of essential nutrients.

118. Wheeting, L. C.
1940. The occurrence of Gray Forest soils in the Puget Sound region. West. Soc. Soil Sci., 6 pp.

Gray Forest soils in the Puget Sound region differ from those described in the literature by having shot pellets in the profile and lacking these attributes: clay accumulation in B horizons; marked structural features; evidence of former grassland status; and $CaCO_3$ in the solum or parent material.

119. Wheeting, Lawrence C.
1936. Shot soils of western Washington. Soil Sci. 41: 35-43.

The "shot clay" soils found in western Washington form only beneath forest vegetation under conditions of restricted drainage. Precipitation and dehydration of soluble iron and aluminum compounds around nuclei during the dry season are suggested as the method by which "shot" are formed.

120. _____
1938. Some forest-soil relationships. Northwest Sci. 12: 63-67.

Discusses influence of soil on tree growth.

121. Whittaker, R. H.
1954. The ecology of serpentine soils. IV. The vegetational response to serpentine soils. Ecology 35: 275-288, illus.

Vegetation on serpentine was compared with that on quartz diorite in the Siskiyou Mountains of southwestern Oregon. Vegetation patterns differed between the two soil materials in almost every respect that can be measured or described.

122. Winjum, Jack K., and Cummings, W. H.
1961. Effects of N, P, and K fertilizers on nursery-grown trees and shrubs common to Douglas-fir forests. Weyerhaeuser Co. Forestry Res. Notes 43, 11 pp., illus.

Growth of trees and shrubs was increased with fertilizer: (a) nitrogen--Douglas-fir, grand fir, Sitka spruce, western hemlock, bigleaf maple, bracken, Oregon grape, salmonberry, trailing blackberry, vine maple, and willow; (b) phosphorus--Douglas-fir, Sitka spruce, western hemlock, and vine maple.

123. Wollum, A. G., II.
1962. Grass seeding as a control for roadbank erosion. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 218, 5 pp., illus.

Grass seeded on a steep roadcut in western Oregon reduced erosion but caused increased runoff during a 3-year-observation period.

124. Wooldridge, David D.
1960. Watershed disturbance from tractor and Skyline Crane logging. Jour. Forestry 58: 369-372, illus.

Soil disturbance after logging with a Wyssen Skyline Crane was only one-fourth that caused by crawler-tractor logging. Skyline logging systems may be advantageous for harvesting timber in municipal watersheds and other areas previously closed to logging because of erosive soil conditions or steep, broken terrain.

125. Wright, Ernest.
1957. Importance of mycorrhizae to ponderosa pine seedlings. Forest Sci. 3: 275-280, illus.

Mycorrhizal fungi were destroyed by chlorpicrin and other poisonous gases used to fumigate soil in a ponderosa pine nursery. Lack of mycorrhizae led to stunted, chlorotic seedlings with significantly poorer survival after outplanting than plants having mycorrhizae.

126. _____ and Bollen, W. B.
1961. Microflora of Douglas-fir forest soil. Ecology 42: 825-828, illus.

Number and kinds of soil micro-organisms varied with season of year, intensity of slash burning, and soil moisture content. Microbial studies should be standardized as to season, soil type, and sampling methods.

127. _____ and Tarrant, Robert F.
1957. Microbiological soil properties after logging and slash burning. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 157, 5 pp.

Burning had greatest effect on microbiological activity in the uppermost surface soil. Intensity of burning was important in determining whether or not microbiological properties were altered. In most cases, unburned and lightly burned soils were not greatly different in number of organisms or ratio of bacteria to actinomycetes. In contrast, marked changes were noted in the microbiological population of severely burned soils.

128. _____ and Tarrant, Robert F.
1958. Occurrence of mycorrhizae after logging and slash burning in the Douglas-fir forest type. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 160, 7 pp., illus.

Number of mycorrhizal Douglas-fir seedlings was related to whether the soil had been burned, but no real difference was found between intensities of burn. More 2-year-old seedlings had mycorrhizal roots than did 1-year-olds. Depth of first occurrence of mycorrhizae on seedling root systems was related to burn intensity on 1-year-old but not on 2-year-old trees. Abundance of mycorrhizae was not associated with intensity of burn nor was occurrence of mycorrhizae associated with soil pH.

129. Youngberg, C. T.
1953. Slash burning and soil organic matter maintenance. Jour. Forestry 51: 202-203.

Severity of the slash burn is reflected in depletion of soil organic matter. Elimination of fire hazard and preservation of soil organic matter should be ultimate aims in slash disposal operations.

130. _____
1955. Effect of soils on the establishment of tree crops. Soil Sci. Soc. Amer. Proc. 19: 86-90.

Soil factors significant in establishment of planted stock and seedlings from natural or artificial seedfall are: texture and structure characteristics of the soil profile as they affect moisture and aeration; depth to ground water; content of soil organic matter; and chemical properties, including soil fertility and occurrence of layers high in soluble salts and toxic substances.

131. Youngberg, C. T.
1955. Some site factors affecting the success of reforestation and afforestation activities in the Willamette Valley foothills. Soil Sci. Soc. Amer. Proc. 19: 368-372, illus.

The narrow range of readily available moisture in many soils of the Willamette Valley is responsible for difficulties encountered in reforestation and afforestation.

132. _____
1957. A modification of the hydrometer method of mechanical analysis for certain western forest soils. Soil Sci. Soc. Amer. Proc. 21: 655-656.

Difficulty in completely dispersing samples for mechanical analysis has been experienced with many western forest soils. In this study, four different methods of dispersing the samples were investigated. For latosolic soils, shaking with sodium hydroxide gave better dispersion than without. With Western Brown Forest soils there was no difference with or without sodium hydroxide.

133. _____
1958. The uptake of nutrients by western conifers in forest nurseries. Jour. Forestry 56: 337-340.

For most species, nutrient removal from the soil was highest for nitrogen, intermediate for potassium, and lowest for phosphorus and calcium. Uptake and content of nitrogen and calcium was lower than for eastern coniferous species and similar for phosphorus and potassium.

134. _____
1959. The influence of soil conditions, following tractor logging, on the growth of planted Douglas-fir seedlings. Soil Sci. Soc. Amer. Proc. 23: 76-78.

Results of soil analysis, particularly in regard to aeration, moisture relationships, and nitrogen content, indicated that tractor roads offer a poor medium for growth of Douglas-fir seedlings.

135. _____
1959. The influence of soil moisture on survival of planted Douglas-fir seedlings on clay soils. Jour. Forestry 57: 842-844, illus.

A rapid increase in rate of planted Douglas-fir seedling mortality is related to soil moisture depletion below "readily available" levels. Influence of site preparation on moisture depletion is discussed.

136. _____
1963. Forest soils--their characteristics in the Pacific Northwest. In Forest Watershed Management Symposium. Oreg. State Univ., pp. 21-32, illus.

Describes major forest soil zones, great soil groups, and humus types found in Oregon and Washington. Influence of topography and parent material is discussed in relation to soil development.

137. _____ and Austin, R. C.
1954. Fertility standards for raising Douglas-fir in forest nurseries. Jour. Forestry 52: 4-6.

Levels of nursery soil fertility necessary for raising good Douglas-fir seedlings are suggested from results of sampling and analyzing surface soils from representative areas in the Douglas-fir region.

138. _____ and Dyrness, C. T.
1959. The influence of soils and topography on the occurrence of lodgepole pine in central Oregon. Northwest Sci. 33: 111-120, illus.

Describes influence of soil drainage and topographic position in relation to cold air drainage on distribution of lodgepole pine as a climax species on pumice soils of central Oregon.

139. Youngberg, Chester T., and Steinbrenner, Eugene C.
1953. Nursery soil research at the Forest Industries Nursery, Nisqually, Washington. Weyerhaeuser Timber Co. Res. Notes, 21 pp.

Aim of research was to produce better balanced nursery stock by use of fertilizers, soil conditioners, and organic matter additions.

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Tarrant, Robert F.
1964. Forest soils research in Oregon and Washington. (A bibliography with abstracts through 1963) U.S. Forest Serv. Res. Paper PNW-15, 29 pp.

This paper references and briefly summarizes all published forest soils research done in Oregon and Washington from 1914 through 1963.

Major findings, or theme, of each reference are briefed, and a subject matter index is provided.

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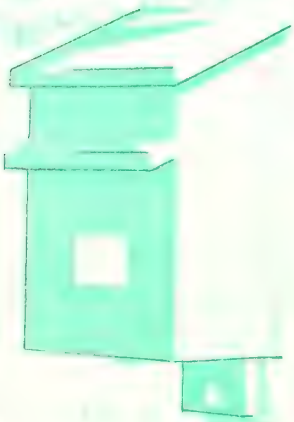
# A TEST

## of Unmanned Registration Stations on Wilderness Trails:

### FACTORS INFLUENCING EFFECTIVENESS

BY WILEY D. WENGER, JR.



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U.S. FOREST SERVICE RESEARCH PAPER PNW-16 1964

U. S. FOREST SERVICE
Research Paper PNW-16

# A TEST

## of unmanned registration stations on wilderness trails: factors influencing effectiveness

By Wiley D. Wenger, Jr.

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FOREST AND RANGE EXPERIMENT STATION
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Portland, Oregon
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
NOVEMBER 1964

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# INTRODUCTION

Better knowledge about wilderness recreation use is an essential base for better decisions on the allocation and management of land for wilderness recreation. On the one hand, the description of recreation use of a specific wilderness area can be immediately useful to the persons faced with maintaining the wilderness environment and deciding how to use money on trail building and maintenance, fire prevention, camp area maintenance and rehabilitation, control of animals and people, and information services to facilitate and enhance use. Such a description to be most useful immediately would include answers to such questions as: How much use does an area get? How is it distributed on the area? Where is overcrowding a problem? How long do people stay? What types of persons are using areas? Are they family groups, organizational groups, or other types of groups? What mode of travel do they use in the area? Are they likely to be familiar with the topography and weather patterns of the area? What recreation do they seek aside from "a wilderness experience"?

On the other hand, better descriptions of wilderness use are essential bases for sound research, which, in turn, is an essential base for better decisions allocating additional land for wilderness recreation, for crystallization of wilderness management objectives, and for long-range wilderness management planning.

On these larger issues, we need research in depth with samples of wilderness users. Samples used for most past wilderness studies have been merely convenience samples;[1] consequently, results, if extended, apply merely to mythical segments of the population as defined by the samples. But administrators are charged with making decisions to serve recognizable public segments, and researchers need to do a better job of basing their studies on samples that are representative of these "real" public segments. Such representative samples are difficult to obtain because wilderness users on any specific area are highly mobile, usually well diffused over a vast acreage, and well distributed in time. Furthermore, field access to them is slow and difficult, even uncertain.

The first problem, then, of obtaining a representative sample of a recognizable, or "real," population of wilderness users is to describe that population well enough to construct a sound sampling plan. An ideal description would include names and addresses of at least one member of each user group. Perhaps registration stations could be used to obtain this description from which needed samples for deeper research could be drawn.

Unmanned registration stations, or registers, have been a common sight for many years on forest recreation areas and trails (fig. 1). One of the more obvious objectives of the registers has been to obtain information about forest recreationists. How effective registers have been or might be for this goal is unreported in the literature, and opinions about their effectiveness vary widely from land manager to land manager. Because unmanned registration stations hold so much promise for obtaining information useful at various levels of wilderness administration and research, we judged it necessary to give them a fair and thorough testing on wilderness areas.

Our initial research on registration stations was aimed at evaluating the pros and cons about how stations should be designed. We also hoped to find out where stations could best

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[1] The Wildland Research Center, University of California. Wilderness and recreation—a report on resources, values, and problems. ORRRC Study Rpt. 3, 352 pp. 1962.
Merriam, L. C., Jr. A land use study of the Bob Marshall Wilderness Area of Montana. Mont. Forest & Conserv. Expt. Sta. Bul. 26, 190 pp. 1963.
Taves, Marvin, Hathaway, William, and Bultena, Gordon. Canoe country vacationers. Minn. Agr. Expt. Sta. Misc. Rpt. 39, 28 pp., illus. 1960.

be located and what system for their use would work best. These issues are discussed in this report, which is written primarily for technicians and researchers who need better methods for obtaining information about wilderness recreation.

The general plan of this report is as follows: First, the study areas are described so that the reader can compare them with what areas he wishes to study; by such comparisons he might better make his own specific applications of our work. Second, our general research procedures are presented. Third, we describe the specifics of our formal experimentation with registration station designs and use the analytical rhetoric of statistics to compare the designs tested. Fourth, we temper the statistical conclusions on designs with a consideration of other factors not included in the statistical analyses. Fifth, factors of the location of stations and system of station use are discussed on the basis of our observations. Sixth, some cost factors are considered. Seventh, a general summary of our conclusions and recommendations is presented.

In other reports stemming from our 2 years of study, we will consider the technical aspects of converting registrations to useful information and will present information obtained about recreation use on the study areas.

Figure 1.—Registration stations in general use vary in elaborateness of design. Usually, the response-eliciting signs say merely "please register," "register here," or perhaps only "registration."

# Study Areas

The general application of our findings to other backcountry areas depends somewhat on the features on and about the areas of application. To permit the reader to compare his areas of interest with the areas involved in our studies, potentially relevant features of the study areas are described in this chapter of the report. Our methods of selecting the two study areas are also described.

"Wilderness" is a generic term which covers a wide range of environmental features. Although "wilderness" has generally come to mean at least "roadless backcountry" to wildland administrators, the term usually carries considerably more complex and variable meaning. For purposes of this study, however, a limited definition will suffice.

For use in this study, "wilderness" is operationally defined as an officially designated U. S. Forest Service wilderness-type area and contiguous roadless land area. The principal recognizable features of official Forest Service wilderness-type areas are described in Appendix A.

The study areas were selected at random from 10 Pacific Northwest areas which satisfied the following criteria (4 other areas were disqualified):

1. Generally representative of the region in pattern and class of use.
2. During the study period, subject to a pattern and class of use normally encountered on the area.
3. Used for several types of recreation.

Areas were selected at random to minimize possible bias influencing selection. The two areas selected were the Three Sisters Wilderness Area and the Mountain Lakes Wild Area. Both are in Oregon.

## The Three Sisters Wilderness Area

The Three Sisters Wilderness Area is located along the crest of the Cascades halfway between the north and south edges of Oregon (fig. 2). The area includes about 197,000 acres, which extend approximately 32 miles north and south and approximately 15 miles east and west. The 53,000-acre tract of unroaded land contiguous to the area on the west side was also included as part of the total area studied. This tract made the study area a maximum of 28 miles wide (east and west).

The area is conveniently reached from the Eugene-Springfield or Bend-Redmond-Sisters areas. About 160,000 people live within 60 miles of the area.[2] Most of the perimeter of the area is accessible via paved or graveled roads.

The topography of the area is highly variable, ranging from extensive gentle slopes to challenging mountain peaks (fig. 3). Elevations range from 2,000 to 10,354 feet. Generally, trail access into the area from the west side is rugged, whereas trail access on the east side, which starts from a much higher base elevation, is extremely gentle.

About 60 access trails[3] lead into the area. These interconnect with a well-developed trail system which includes about 45 miles of the popular Oregon Skyline Trail. Access trails are well distributed around the perimeter. Only two short sections of the extensive perimeter are gentle and open enough to permit access off a well-defined trail.

A number of very popular lakes are adjacent to the area on the east and north sides, and

[2] Table 8, page 39-17, of U.S. Census of Population: 1960. Final Report PC(1)—39A. 1961.

[3] These include informal trails or clearly evident routes which are defined by use. A number of these are not on the official Forest Service trail system.

good fishing rivers are adjacent on the west side. The area is surrounded by roadside campgrounds. Three resorts and a pack station are adjacent to the area on the east side, where extremely heavy campground use occurs during the summer months.

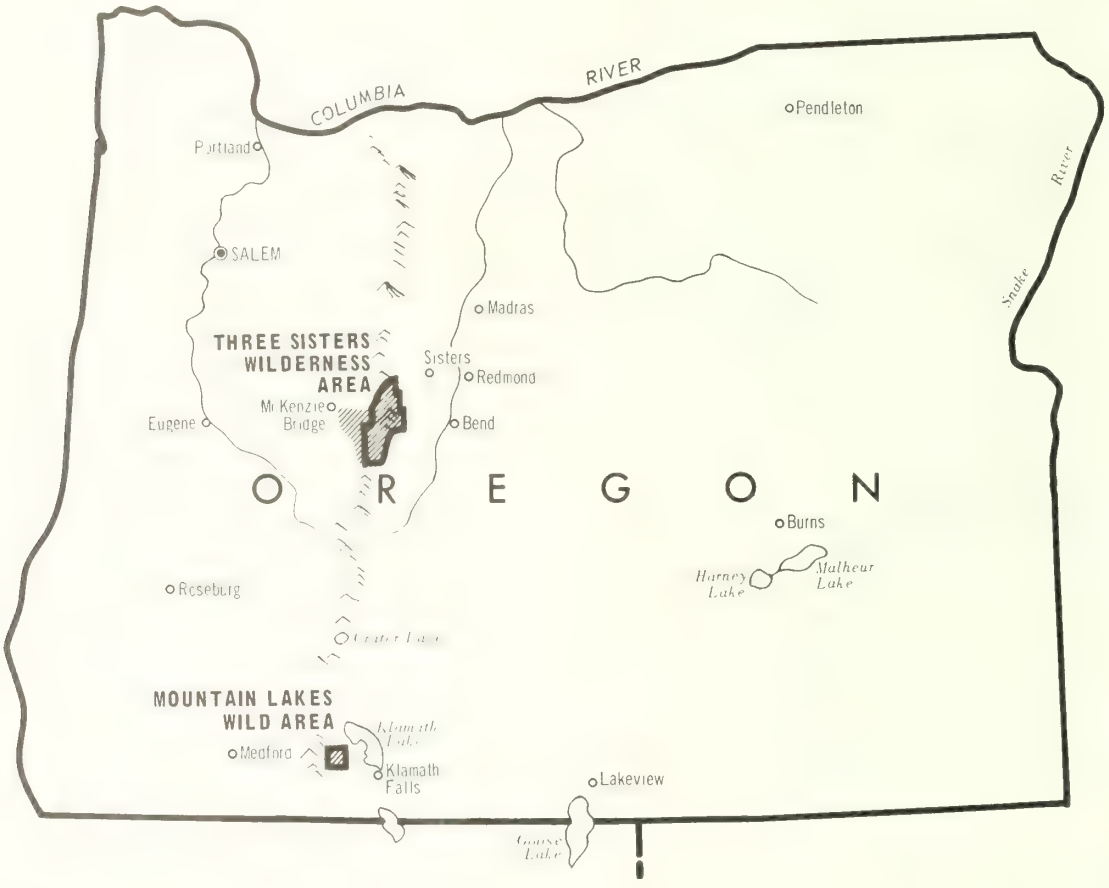


Figure 2.—The two study areas are located along the crest of the Oregon Cascades.

## The Mountain Lakes Wild Area

The Mountain Lakes Wild Area includes about 23,100 acres of high country. It is located 3 miles east of the crest of the Cascades in southern Oregon between Medford and Klamath Falls.

A population of about 120,000 lives within 60 miles of the area.

The area was readily accessible from Klamath Falls over a paved highway and from Medford via Ashland over a paved highway except for about 6 miles of graveled road. Travel distance from Klamath Falls is about 25 to 35 miles (depending on access point) and from Medford, 30 to 40 miles. Unpaved forest roads provide access to trailheads from the paved highway which loops around the east and north sides of the area.

All users enter the area on six access trails. Trailheads are all well defined and are well distributed around the perimeter, with access trails leading in from all four sides of the area. Forest roads to the trailheads on the east and

Figure 3.—The Three Sisters Mountains provide rugged mountain scenery on the north half of the Three Sisters Wilderness Area.

Figure 4.—Lake Harriette is a principal point of attraction in the Mountain Lakes Wild Area.

south sides are hazardous for standard highway vehicles, but trailheads on the north and east sides are easily accessible.

The area is 36 square miles in the shape of a square. The contiguous unroaded acreage was not extensive and was being roaded and logged during the study period.

Elevations of the area range from about 5,000 to 8,200 feet. The boundaries include eight peaks over 7,500 feet. The mountains form a large rim about the heart of the area which includes numerous small lakes. The largest of these is Lake Harriette, the major point of attraction on the area (fig. 4). Although the area receives a deep snow accumulation during the winter, all but two small streams dry up during the late summer.

Pack and saddle stock are available at a pack station near the west boundary. However, the area is too small for long trips with stock, and forage on the area is extremely scarce.

Influences from adjacent recreation complexes would come largely from the Lake of the Woods which is 2 miles from the west boundary. Around this large lake are three organization camps, two popular forest camps, a resort, numerous summer residences, and a pack station. The developed campgrounds here are the only ones near the wild area. The principal recreation emphases at this lake are fishing, speed boating, and water skiing.

The features of these two study areas can be summed as follows: One is large, and one small. Both are within easy driving distance of moderately large population centers (for the Pacific Northwest). All sides of each area are readily accessible by road, with two sides of each being served by paved highways that are nearly adjacent to the officially designated wilderness boundaries; both areas have some gentle access trails leading to scenic attractions. A full spectrum of wilderness-type recreation activities is available between the two areas, and both areas have developed forest campgrounds on their perimeter. One area (the Three Sisters) is well known among backcountry enthusiasts; the other is relatively unknown.

These features offered considerable, desirable variation in our tests of unmanned registration stations on wilderness trails.

# General Research Procedures

In this chapter, we describe the general design of the study and the specific methods of obtaining our data for evaluations. Later chapters discuss details on the data, analyses, and evaluations.

## Overview of the Study Design

In both years of the study, the objective was to determine if unmanned registration stations might be designed and employed effectively to obtain use information from recreationists on wilderness trails. If registration stations seemed at all effective, we wished to know what physical factors seemed to contribute most to their effectiveness.

Registration stations were located on all entry trails at or near their junction with an access road. Signs requested that one person from each group register for the group. The registration forms asked several easily answered questions about the group.

How recreation groups responded to a station design was the criterion of its effectiveness. To determine group responses, we interviewed groups along the trail beyond the station. We also examined the quality of information obtained at the station. Evaluations of design and other factors of station use were made on the basis of statistical analyses and systematic observation.

The rest of this chapter will amplify the methods used for obtaining our data.

## Terminology

Special terms used in describing the methods, data and the subsequent analyses are as summarized below:

Block—a geographic subunit:

Block I—west side, Three Sisters Wilderness Area,

Block II—east side, Three Sisters Wilderness Area, and

Block III—Mountain Lakes Wild Area.

Area—one of the two study areas.

Survey trail—one of the trails on which recreationists were interviewed.

Sampling unit—one group of trail users.

Treatment—a registration station with a specific combination of sign wording and box design:

| Treatment number | Combination |
|---|---|
| 1 | Sign 1, card-type box |
| 2 | Sign 2, card-type box |
| 3 | Sign 3, card-type box |
| 4 | Sign 1, book-type box |
| 5 | Sign 2, book-type box |
| 6 | Sign 3, book-type box |

Group or party—one or more persons traveling and/or camping together as a unit.

Group leader—in informally structured groups, a person who takes the initiative in registration or interviews, or both; in groups with established hierarchies, the regular leader, e.g., father of a family group, leader of a mountain climbing party.

Planned interviews—interviews with parties entering the study areas via a survey trail on the prescribed days for interviewing on that trail.

Special interviews —interviews outside the scope of the prescribed sampling plan for interviewing; includes interviews with leaving parties, parties on nonsurvey trails, and parties on survey trails on nonprescribed days.

Error—each discrepancy of registration data from actual fact in (1) number of groups, (2) number of individuals, (3) name-and-address combinations for registrants. (Errors are additive irrespective of direction.)

Repeater—a group containing one or more persons who had been exposed to a registration station on a trip to a study area prior to the trip of the interview.

Group visit—one trip to an area by a group of persons.

Individual visit—one trip to an area by one person. (A group of eight persons on one trip would count as one group visit and eight individual visits.)

Nonregistrant—a group that fails to register at a station.

Overregistration—registration of more groups or individuals in groups than were present on a trail; multiple registration by one group on one visit.

## Registration Station Designs Location, and System of Use

The two elements of registration stations that seemed a priori most important to station success were selected for testing. These elements were (1) the sign requesting registration and (2) the method of storing completed registrations, that is, the style of registration box. In total, we tested six variations of registration station design in 1961. These variations consisted of all combinations of three differently worded signs and two different styles of form-holding box. In 1962, we tested one modified station design against 1961 designs.

Except for the two elements being tested, all stations were as similar in design as possible. Boxes were also designed to be adequate protection for forms against weather and animals. Two chained ballpoint pens and one pencil (unchained) were placed with each box. A small plastic calendar was fastened on the underside of the lid of each station in 1961 and on the top of the lid in 1962. All boxes were wood and finished with flat, dark-brown stain. All signs were made with silk-screened black letters on a yellow background; paints were waterproof enamel on tempered hardboard.

Stations were located on all known access trails on the perimeter of each study area (figs. 5 and 6). They were fastened to convenient trees or stumps or to posts set alongside the trail as close to the trailhead[4] as local conditions permitted.

Signs.—The 1961 sign wordings are as shown on page 9.

The signs varied in tone from mildly soliciting to mildly demanding. Variations were achieved by the use of the word "please" or "must" and by explaining or omitting the reasons for registering. Signs were otherwise as nearly alike as possible.

Signs were located above or otherwise as close to the registration boxes as possible so that they would be readily visible to persons approaching the station. When signs were not on the same tree or post as the station, they were located so that the box could also be seen by a person as he read the sign.

Boxes.—In 1961, we used two boxes (fig. 7). One box, called the card-type, was designed so that a registrant obtained a blank registration card by opening the lid and removing the form from the top section of the box. After completing it, he was instructed to drop it through a slot to the bottom section of the box. Access to the bottom of the box was achieved only by removing two phillips screws holding the inner separator between the bottom and top halves of the box. As a consequence, a person's replies to the questions on the registration form were protected from public view.

The other 1961 box, the book-type, was designed so that when a registrant lifted the lid he encountered a registration book, i.e., forms held in looseleaf binder rings. Upon completion of his registration, he would merely close the lid, leaving the information available to public scrutiny along with previous registrations.

Combinations of 1961 signs and boxes resulted in six design variations, or treatments, as presented in the terminology section.

[4] A trailhead is the point at which a trail begins, i.e., the junction of a road and trail.

ALL PARTIES MUST

# REGISTER

WHEN ENTERING AND LEAVING THIS AREA

This will help us to :

Locate you in case of emergency at home
Plan and maintain trails for you
Meet your needs in this area
Protect this area for you to enjoy

GROUP LEADER, REGISTER HERE

Many thanks ! Have a pleasant trip !

U.S. FOREST SERVICE

Sign 2 1961 SIGNS

ALL PARTIES PLEASE

# REGISTER

WHEN ENTERING AND LEAVING THIS AREA

GROUP LEADER, REGISTER HERE

Many thanks ! Have a pleasant trip !

U. S. FOREST SERVICE

Sign 1

ALL PARTIES MUST

# REGISTER

WHEN ENTERING AND LEAVING THIS AREA

GROUP LEADER, REGISTER HERE

Many thanks ! Have a pleasant trip !

U.S. FOREST SERVICE

Sign 3

1962 SIGN

**One Person From Each Party**

# REGISTER

**When Entering This Area**

***This will help us meet your needs in this area***

**Register Here**

U.S. FOREST SERVICE

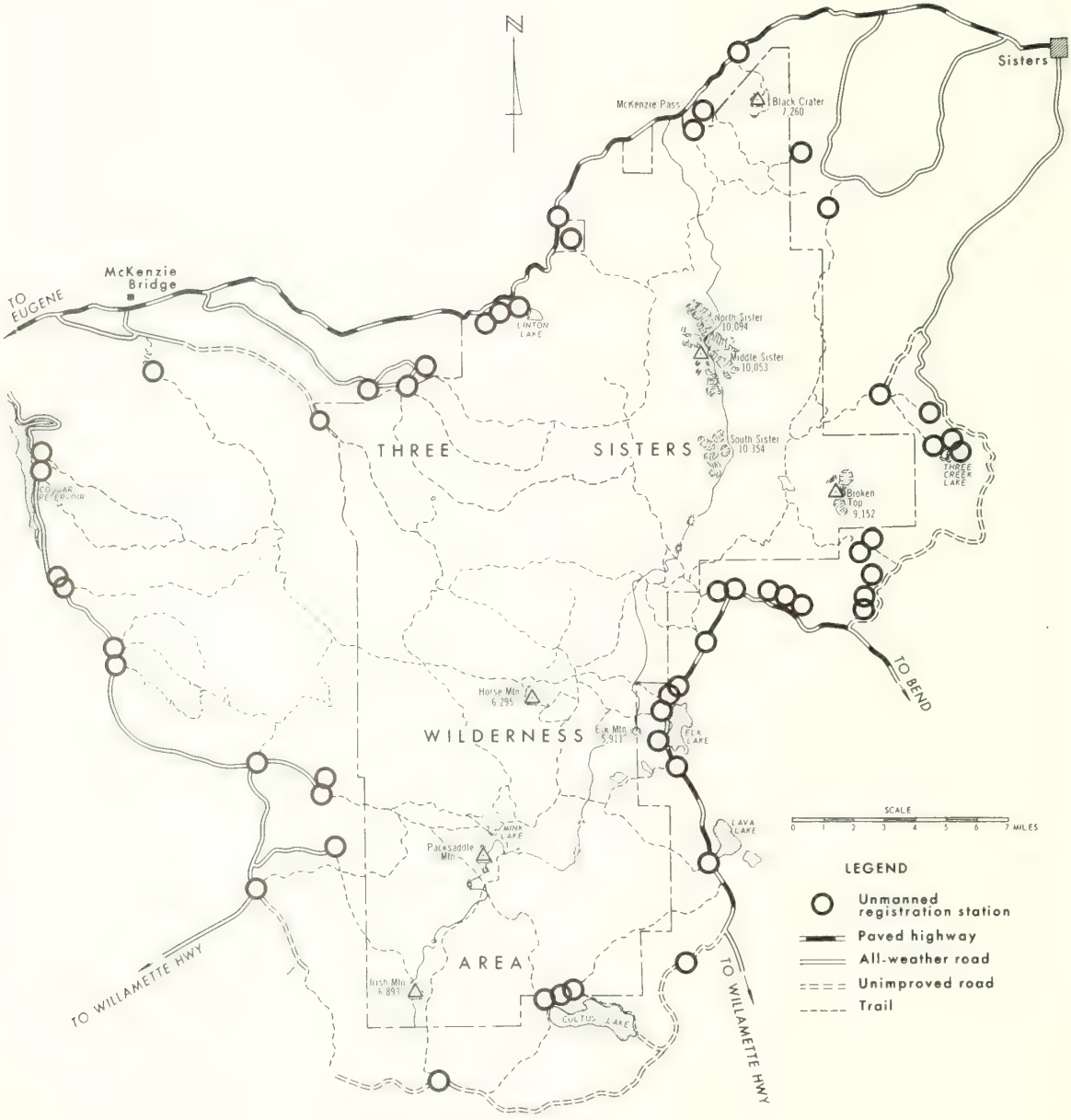


Figure 5.—All known access trails into the Three Sisters Wilderness Area and contiguous roadless area had a registration station at the trailhead.

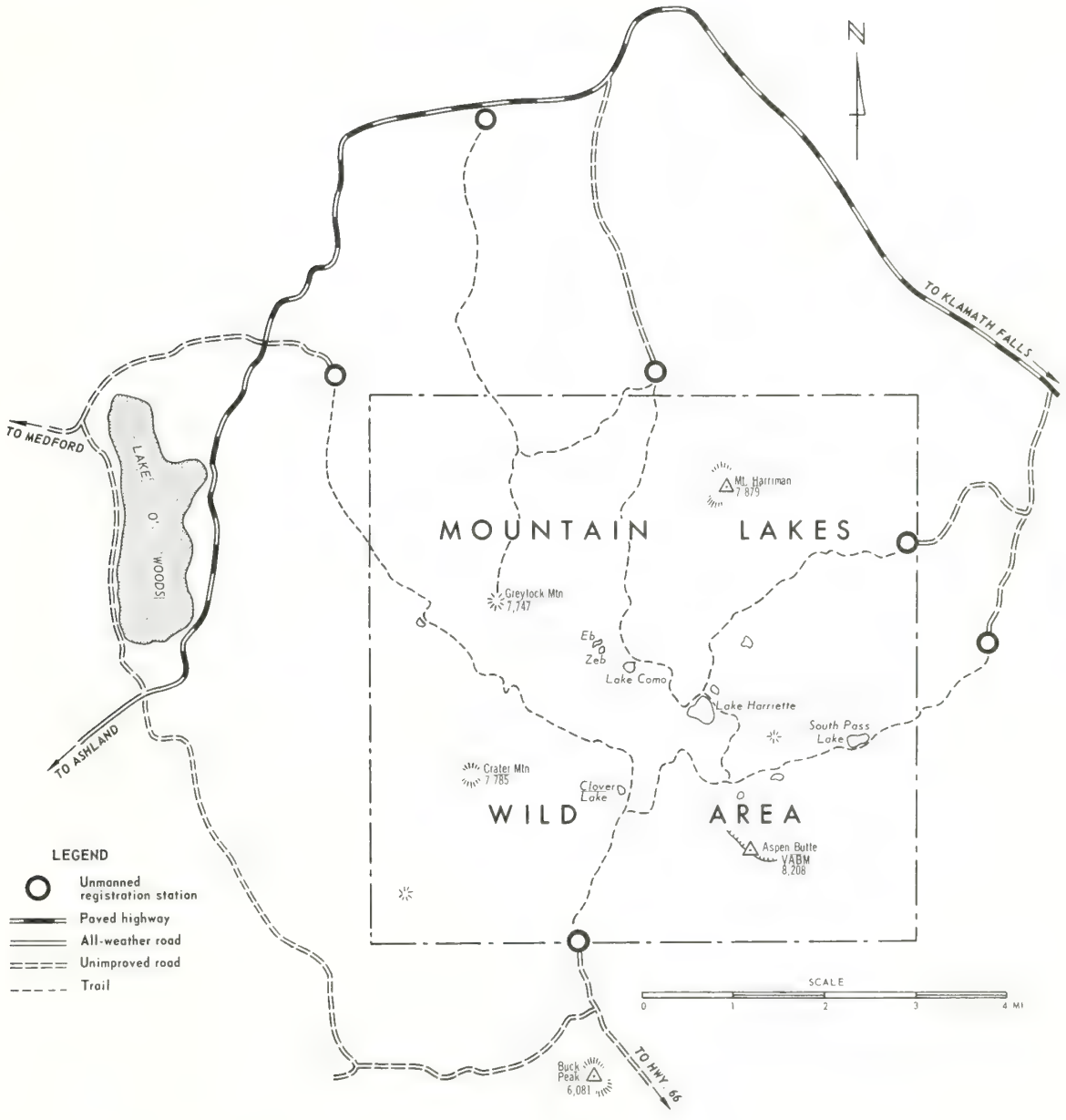


Figure 6.—All six of the trails into the Mountain Lakes Wilderness Area had registration stations at the trailheads.

Figure 7.—
Combinations of two different box designs and three response-eliciting sign designs were tested in 1961.

Registration forms for both types of boxes requested the same information. Wording and format were identical except that each sheet of the book-type form provided for three separate registrations (see page 14). Although the variable represented by forms was controlled as much as possible, the book-type form obviously created more visual impact and could be expected to stimulate most first-impression anxiety about what was expected of registrants.

Figure 8.—The station design tested in 1962 employed a map of the area as an additional service and attraction.

Registration cards were printed on IBM-type cards because (1) they were less costly to buy, print, and number than any other cardstock, and (2) a preliminary study of box dimensions showed that about three times the capacity could be handled if the forms were not folded before placing through the slot—people have generally been conditioned not to fold IBM-type cards. Heavy materials were used to permit use of forms when wet from exposure. Book-type forms were printed on 8-1/2- by 11-inch cover stock.

In 1962, we used but one registration station design with modifications based on 1961 tests. The most significant of these modifications were (1) a change in sign wording and (2) addition of a map as an integral part of the station. The registration form was also redesigned to improve clarity and gain additional information.

The sign wording in 1962 was firm in tone, though courteous, with no "frills" (page 9).

The card-type box was used in 1962 without significant modification. However, a plastic-laminated map of the principal area served by the particular access trail was mounted on a backing board above the registration box. The position of each particular registration station was marked on its map in words, "you are here," with an appropriate circle. The rationale of the maps, in addition to providing a needed service, was to increase the attraction of the station (fig. 8). Once a trail user had paused to look at the map, he might be more likely to register at the box in front of him.

Stations were located on trails as close to the trailheads as possible. An effort was made to cover every shortcut in addition to main trails. Additional registration stations were placed at the two pack stations serving the areas in 1962.

It was requested that each group be registered by one person. In 1961, groups were asked to register both when entering and leaving the areas. In 1962, only entering registration was requested.

REGISTRATION BOOK

Please answer all questions. One person only register for each group.

Name of group leader _____

Street or Box _____

City and State _____

Date _____ Time _____ ☐a.m. ☐p.m.

The number of persons in this group
16 years of age and older _____
younger than 16 years _____

The purpose of this trip is
(check one) ☐recreation
☐Forest Service work
☐other work _____ (what?)

(check one) ☐We are entering area
☐We are leaving area

(check one) ☐We are walking
☐We are riding horses
☐Other _____ (what?)

(check one) ☐We are backpacking
☐We are stock packing
☐We have no packs

We're going or have been in the area
(check one) ☐less than 1 mile
☐1 mile to 15 miles
☐more than 15 miles

Please answer all questions. One person only register for each group.

Name of group leader _____

Street or Box _____

City and State _____

Date _____ Time _____ ☐a.m. ☐p.m.

The number of persons in this group
16 years of age and older _____
younger than 16 years _____

The purpose of this trip is
(check one) ☐recreation
☐Forest Service work
☐other work _____ (what?)

(check one) ☐We are entering area
☐We are leaving area

(check one) ☐We are walking
☐We are riding horses
☐Other _____ (what?)

(check one) ☐We are backpacking
☐We are stock packing
☐We have no packs

We're going or have been in the area
(check one) ☐less than 1 mile
☐1 mile to 15 miles
☐more than 15 miles

Please answer all questions. One person only register for each group.

Name of group leader _____

Street or Box _____

City and State _____

Date _____ Time _____ ☐a.m. ☐p.m.

The number of persons in this group
16 years of age and older _____
younger than 16 years _____

The purpose of this trip is
(check one) ☐recreation
☐Forest Service work
☐other work _____ (what?)

(check one) ☐We are entering area
☐We are leaving area

(check one) ☐We are walking
☐We are riding horses
☐Other _____ (what?)

(check one) ☐We are backpacking
☐We are stock packing
☐We have no packs

We're going or have been in the area
(check one) ☐less than 1 mile
☐1 mile to 15 miles
☐more than 15 miles

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APPROVAL EXPIRES 6/30/62

## Interview Sample Survey Plans

By interviewing trail users beyond the stations, we were able to make direct field comparisons of actual and registered use. Stations could not be checked continuously. Consequently, the most serious problem in the use of interviewers was to obtain representative estimates of responses at a feasible cost.

The sampling plans were designed to eliminate the maximum number of experimenter biases and to give each group an equal chance of occurring in the sample. Lacking perfect information about the factors affecting groups' responses and the occurrence of types of groups over the areas, we used a plan that best seemed to randomize these factors and thereby to result in a sample representative of all area users.

One major difference between the 1961 and 1962 sampling plans stemmed from the need to minimize trail-associated bias in our test of 1961 designs. The other major difference was in our basis for selection of trails on which to interview—in 1961, we selected six trails at random on each block (see "Terminology," page 7); in 1962, we interviewed only on trails with a minimum expected use of one group per day.

Groups were the basic population elements because responses were measured on groups. Field conditions made it necessary to sample the population in clusters of groups, but field conditions also made it seem reasonable to assume group responses to be independent of one another.[5]

Details of each year's plan are described below.

### 1961 PLAN

Each 1961 sample group could not be exposed to all six treatments (see "Terminology," page 7), and, indeed, memory of prior treatments would confound all but first responses; consequently, responses were measured on groups in independent subsamples for each treatment.

Unique factors associated with specific trails could influence group responses at stations. To prevent confounding the response variable, we did the following in the sampling plan:

1. Equal interview time was allowed to each trail used in the survey.
2. On each survey trail, treatments were rotated so that each treatment occurred on each trail for one interview period; with six treatments, we had six interview periods on each survey trail.

Interviewer time was limited by costs; accordingly, the number of survey trails was limited to six on each block. This number permitted a balanced sample design on each block—six treatments by six trails—which spread our available time out over the maximum possible number of trails.

The six trails were selected at random within each block on the Three Sisters Wilderness Area (a selection of 12 trails out of the known 45). All six trails of Block III (corresponding to the Mountain Lakes Wild Area) were used. Only trails a mile or more in length or connecting with other interior trails were included in the trail population from which sample trails were drawn.

In 1961, interviewing was conducted in periods evenly spread from the early part of June to late October. Such a long season was used to obtain responses from all classes of user groups, from early fishing to elk hunting groups, and thereby to test the stations with a full diversity of recreationists.

The 1961 interview periods on each trail were from 8 a.m. to 4 p.m.

Initially, then, six trails were used in the survey on each of the three geographically distinct blocks. Block III was dropped midway through the study because of trail use too light to obtain sufficient interviews. In total, interviewers spent 92 days on survey trails in 1961.

Because of the failure to encounter users during some interview periods, the balanced design of the experiment suffered, and the overall sample was considerably smaller than hoped for. Fortunately, data were collected for each treatment on each block of the Three Sisters Wilderness Area, and data collected were sufficiently

[5] Readers who wish a fuller discussion of this assumption may request a report being prepared on survey methodology used with registration stations on wilderness areas.

well distributed among trails to permit generalizing to all trails on the area. Because of the small sample size, only large differences between treatments would likely be indicated by the statistical analyses.

### 1962 PLAN

The 1961 sampling plan was designed around the experimental test of design variations. In 1962, one "standard" design was used and was compared with designs used in 1961. The comparison was less rigorous than that between treatments in 1961, but provided some basis for evaluating the general effect of 1962 modifications.

In the 1962 sampling plan, an attempt was made to improve the efficiency of sampling. Accordingly, predicted use of trails for 1962 was calculated from 1961 registration data. Ten trails were purposively selected from the 16 trails having an average use of at least one group per day. The 37 interview periods available were all assigned to these 10 trails[6] in about equal numbers by random drawing. Interview periods included 25 weekend-days and holidays and 12 weekdays. Each period was from 8 a.m. to 3 p.m.

Interviews were obtained from all entering and leaving groups encountered during interview periods, except that no group was interviewed more than once during a visit.

## Collection of Information about All Stations

Information was also collected periodically throughout the field seasons from and about all registration stations—not only those used in the sample survey. All completed registration forms were collected, observations about vandalism and other elements of interest were made, and necessary maintenance was done to restore the stations to good condition. From this information, we derived quantified measures of three factors which we used in making additional comparisons of 1961 designs. These factors were vandalism to stations, accuracy of key items on forms, and spurious comments on forms. Specifics of this data categorization are discussed with the presentation of analyses.

The statistical analyses considered only those aspects of response to designs which could be quantified. They represented but one type of evidence, albeit a powerful one, which assumed adherence to formally prescribed rules. Adherence to the formal models is rarely perfect, however, and other types of evidence are frequently of value, too, if carefully gathered and used. To supplement our statistical analyses in this study, intensive observations relevant to use of stations were made throughout the field seasons by the author and his assistant. The same two people handled the study both years and were able to make numerous informal manipulations of equipment, tests, and specific observations to follow up hunches about how people responded to the stations. Care was always made in these informalities not to influence, or disturb, the formal aspects of the study. Abundant notes and records of our observations were made during both seasons; these informal findings were used to temper and supplement the formal statistical comparisons and will be presented following the statistical analyses.

[6] By 1962, a total of 53 trails were known on the Three Sisters Wilderness Area and 6 on the Mountain Lakes Wild Area. All known trails had registration stations on them for collecting use information on the study area. The 10 sample survey trails were all on the Three Sisters Wilderness Area.

# Statistical Analyses of Station Design

Through the statistical analyses, we tried to learn which sign and box design resulted in the most desirable responses of recreation groups. Comparisons of signs and boxes were made in 1961, using data from two basic sources: (1) the interview sample survey and (2) information from all stations.

A series of nine analyses was made of data from the first source, and three from the second source. These analyses are discussed in sections entitled, "1961 Interview Sample Survey","Information from All 1961 Stations", and "Discussion of the 1961 Statistical Analyses." In 1962, a modified station design was compared for effectiveness with all but one 1961 design, and the analyses are discussed in the section, "The Effectiveness of 1962 Design Modifications." Data on the 1962 design came entirely from the 1962 interview sample survey.

## 1961 Interview Sample Survey

Interviewers collected information about (1) the response of each sampled group at particular stations and (2) a few characteristics of each group, including whether or not group members had previously been on trails with registration stations. In this section, we present details of the type of data collected, the rationale of the ways we aggregated the sample, and the results of the series of data analyses.

The sampling plan resulted in a smaller sample size than we had hoped for, and by the middle of the 1961 season, we began to seek "unplanned," or "special," data sources in addition to those in the plan. The plan had specified that "entering" groups would be included in the sample; to add to our "special" sample, we began to interview "leaving" groups not previously interviewed. We compared these latter interviews with information on the registration stations at the time and place groups had purported entering. If overregistration by groups had occurred frequently, errors would have been underestimated by the incorporation of this special interview data into that from the planned sample; however, our experiences with groups interviewed by plan indicated very little overregistration—the bias from this source in special interviews seemed likely to be negligible. Other special interviews were obtained by interviewing on five trails not in the planned sample and by interviewing a few extra days on planned trails. To preserve the rigor of our planned survey, yet use all our survey data, separate statistical analyses were made with and without the special data.

Another separation of the total obtained sample seemed necessary because of the occurrence of "repeaters" in the sample. Repeaters were those groups who had encountered a station on some visit prior to that on which interviewed (no groups were interviewed more than once). The initial perception of stations by repeat visitors might have carried over to subsequent visits, even though different treatments were encountered on return trips. To be free of this confounding variable, planned data analyses were also made with repeater data removed.

A summary of interviews obtained in each of the sample aggregations is shown in table 1.

Three measures of responses were derived from comparisons of interview and registration information for each group:

1. The number of registered groups for each interviewed group.

2. The number of individuals reported by each group on the registration form and the number actually seen in the group.
3. The apparent accuracy of the name and address of each group registrant.

Table 1.—Summary of interviews obtained by blocks

| Item | Block | | | Total |
|---|---|---|---|---|
| | I | II | III | |
| Number of interviewer days | 35 | 41 | 16 | 92 |
| Number of interviews: | | | | |
| Planned | 38 | 15 | 0 | 53 |
| Special | 7 | [1]28 | 6 | 41 |
| Total | 45 | 43 | 6 | 94 |
| Number of individuals in groups: | | | | |
| Planned interviews | 128 | 57 | 0 | 185 |
| Special interviews | 29 | [1]118 | 36 | 183 |
| Total | 157 | 175 | 36 | 368 |
| Number of repeaters: | | | | |
| Planned interviews: | | | | |
| Groups | 9 | 7 | 0 | 16 |
| Individuals in groups | 35 | 18 | 0 | 53 |
| Special interviews: | | | | |
| Groups | 4 | [1]13 | 2 | 19 |
| Individuals in groups | 21 | [1]53 | 7 | 81 |
| Total: | | | | |
| Groups | 13 | 20 | 2 | 35 |
| Individuals in groups | 56 | 71 | 7 | 134 |

[1] Includes 3 groups observed that were not interviewed—a total of 10 individuals.

The comparisons were quantified in terms of the error effect on registration information as follows:

1. Group errors—the error in registered number of groups resulting from a group's response. If a group registered properly, its error score was "0." Groups that failed to register were scored "1." If more than one registration was left by a group at one time, its score was the number of surplus registrations.
2. Individual errors—the total number of individuals erroneously reported by a group when responding at a particular time.
3. Name-and-address errors—the number of erroneous, incomplete, or surplus name-and-address combinations resulting from a group's response.

Errors were summed irrespective of the sign of each; it was irrelevant in the comparison of treatments whether an error stemmed from too much or too little registration information.[7]

The total sample data are shown in tables 2, 3, 4, and 5.

The distributions of errors were discrete, nearly binomial, and highly skewed; the number of groups and persons encountered on each treatment was highly variable; and the quantity of data was clearly less than optimum. Use of a nonparametric test for analyses of these data seemed preferable, as the requirements for the distribution are less severe and the potential for generalization is greater than with parametric tests.

Table 2.—Number of group errors

| Number of groups | Errors per group | Total errors |
|---|---|---|
| 64 | 0 | 0 |
| 28 | 1 | 28 |
| 1 | 2 | 2 |
| 1 | 3 | 3 |
| 94 | -- | 33 |

Table 3.—Number of name-and-address errors

| Number of groups | Errors per group | Total errors |
|---|---|---|
| 59 | 0 | 0 |
| 32 | 1 | 32 |
| 2 | 2 | 4 |
| 1 | 3 | 3 |
| 94 | -- | 39 |

Table 4.—Number of individual errors

| Number of groups | Individual errors per group | Total individual errors |
|---|---|---|
| 55 | 0 | 0 |
| 7 | 1 | 7 |
| 10 | 2 | 20 |
| 10 | 3 | 30 |
| 7 | 4 | 28 |
| 2 | 5 | 10 |
| 2 | 6 | 12 |
| 1 | 17 | 17 |
| 94 | -- | 124 |

Table 5.—Mean number of individual errors per individual per group

| Number of groups | Mean errors |
|---|---|
| 55 | 0.000 |
| 1 | .100 |
| 1 | .250 |
| 1 | .266 |
| 2 | .500 |
| 1 | .667 |
| 32 | 1.000 |
| 1 | 2.000 |
| 94 | -- |

[7] On the other hand, adjustments of data to obtain use estimates must be based on algebraic summation of errors.

The Kruskal-Wallis test was appropriate. Assuming that each group was independent, we computed the statistic H from the rank error score for each. The usual correction for ties in rank scores was made. The probability of an H as large or larger occurring by chance was determined by use of a chi-square table[8].

The analyses were made to determine if the frequency of errors was significantly different for different boxes, different signs, and, when data was sufficient, for different blocks. If the probability was less than 5 in 100 that a population difference occurred, the error frequency in a particular test was concluded to be significantly associated with the design or blocks involved.

The same statistical techniques were used for each of the error types—group, individual, and name-and-address—by each of the sample aggregations. The three sample aggregations were as follows:

| Data source numbers | Data sources |
|---|---|
| 1 | Planned interviews |
| 2 | Planned interviews except repeater groups |
| 3 | All interviews except repeater groups |

In interpreting the analyses, most emphasis, or weight, was given to those analyses on sample aggregations with the best control of extraneous and confounding influences. Ranked highest in interpretation were the analyses on data source 2, second were analyses on data source 1, and third were analyses on data source 3.

A detailed example of the application of the Kruskal-Wallis test is presented in Appendix D with data and summaries of all analyses. Conclusions are summarized below by type of error and data source:

[8] Siegel, S. Nonparametric statistics for the behavioral sciences. 312 pp. New York: McGraw-Hill Book Co., Inc. 1956.

| Data source | Most effective design: Box No. | Most effective design: Sign No. |
|---|---|---|
| For group errors: | | |
| Planned | 2 | ([1]) |
| Planned minus repeaters | 2 | ([1]) |
| Planned plus special minus repeaters | ([1]) | ([1]) |
| For individual errors: | | |
| Planned | 2 | ([1]) |
| Planned minus repeaters | ([1]) | 2, 3 |
| Planned plus special minus repeaters | ([1]) | 2, 3 |
| For name-and-address errors: | | |
| Planned | 2 | ([1]) |
| Planned minus repeaters | 2 | 2, 3 |
| Planned plus special minus repeaters | ([1]) | 2, 3 |

[1] Sample differences between designs are statistically nonsignificant.

Fewer group registration errors occurred on box 2, the book-type box, than on box 1, the card-type box. Sign wording seemed to have little effect on group registration errors in this test.

Signs 2 and 3, the most firmly toned signs, yielded fewer individual registration errors than sign 1, the least firmly toned one. But the weight of evidence indicated that box differences were not significant in effect on these errors.

Fewer name-and-address errors occurred on box 2 than on box 1 and on signs 2 and 3 than on sign 1.

On the basis of the sample survey, significant differences were indicated often enough and consistently in the same direction so that it seemed reasonable to assert that box 2 and either sign 2 or sign 3 were the most effective designs for obtaining information on the number of group visits, number of individual visits, and names and addresses of registrants. The analyses of the frequency of errors that occurred on block I and block II indicated that no significant differences existed between these blocks; therefore, the conclusions were not influenced by block differences.

The data are rearranged and presented in tables 6 to 8 to show the percentages of groups and individuals registered for selected sample aggregations[9]. Two most striking features of these tables are (1) the percentage registered on box 1-sign 1 is markedly lower than for all other combinations and (2) except for the box 1-sign 1 combination, percentages registered are all high—between 78 and 100 percent. The Kruskal-Wallis test was incapable of testing interaction between boxes and signs, but it seemed from the percentages shown that the box 1-sign 1 combination was probably responsible for both box 1 and sign 1 being significantly inferior in the foregoing analyses. We could not see, from other inspection of the raw data, any peculiarities that might explain the probable interaction with box 1 and sign 1.

[9] In these tables, percent registered reflects compensating errors, i.e., overregistration canceled underregistration on a 1-to-1 basis.

Table 6.—Registration of groups (planned interviews less repeaters), by various combinations of boxes and signs

| Sign No. | Box 1 | | | Box 2 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual | Registered | | Actual | Registered | | Actual | Registered | |
| | Number | Number | Percent | Number | Number | Percent | Number | Number | Percent |
| 1 | 7 | 3 | 42.8 | 7 | 6 | 85.7 | 14 | 9 | 64.3 |
| 2 | 5 | 4 | 80.5 | 11 | 11 | 100.0 | 16 | 15 | 93.8 |
| 3 | 1 | 1 | 100.0 | 6 | 5 | 83.4 | 7 | 6 | 85.7 |
| Total | 13 | 8 | 61.5 | 24 | 22 | 91.7 | 37 | 30 | 81.2 |

Table 7.—Registration of groups (planned plus special interviews less repeaters), by various combinations of boxes and signs

| Sign No. | Box 1 | | | Box 2 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual | Registered | | Actual | Registered | | Actual | Registered | |
| | Number | Number | Percent | Number | Number | Percent | Number | Number | Percent |
| 1 | [1]10 | 4 | 40.0 | [1]7 | 6 | 85.7 | 17 | 10 | 58.8 |
| 2 | [2]7 | 6 | 85.7 | [1]15 | 13 | 86.7 | 22 | 19 | 86.4 |
| 3 | [3]3 | 3 | 100.0 | [4]17 | 15 | 88.2 | 20 | 18 | 90.0 |
| Total | 20 | 13 | 65.0 | 39 | 34 | 87.2 | 59 | 47 | 79.7 |

[1] Includes one horseback group of four persons not registered.
[2] Includes two horseback groups of nine persons registered.
[3] Includes one horseback group of four persons registered.
[4] Includes two horseback groups of 21 persons—23 persons were recorded. Also includes one party of four persons on two trail motorscooters not registered.

Table 8.—Individuals registered (planned plus special interviews less repeaters), by various combinations of boxes and signs

| Sign No. | Box 1 | | | Box 2 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual | Registered | | Actual | Registered | | Actual | Registered | |
| | Number | Number | Percent | Number | Number | Percent | Number | Number | Percent |
| 1 | [1]38 | 6 | 15.8 | [1]23 | 18 | 78.3 | 61 | 24 | 39.3 |
| 2 | [2]28 | 25 | 89.3 | [1]66 | 52 | 78.8 | 94 | 77 | 81.9 |
| 3 | [3]13 | 13 | 100.0 | [4]66 | 59 | 89.4 | 79 | 72 | 91.1 |
| Total | 79 | 44 | 55.7 | 155 | 129 | 83.2 | 234 | 173 | 73.9 |

[1] Includes one horseback group of four persons not registered.
[2] Includes two horseback groups of nine persons registered.
[3] Includes one horseback group of four persons registered.
[4] Includes two horseback groups of 21 persons—23 persons were recorded. Also includes one party of four persons on two trail motorscooters not registered.

In summary, the 1961 interview survey analyses indicate the following:

1. More groups registered at book-type registration stations than card-type. Sign tone seems to have had little effect on whether or not groups registered.
2. Once groups stopped to register, they tended to do a more accurate job of reporting the number of individuals and the names and addresses of the group leaders at stations with the more firmly toned signs.
3. Names and addresses tended to be reported more accurately at book-type stations than card-type.
4. The poor response to the mildest sign combined with the card-type box probably contributed heavily to the foregoing results.

In general, use of the book-type box and either of the two most firmly toned signs resulted in the best responses. But it is likely that the only significantly inferior design was the combination of the card-type box with the mildly toned sign. Other evidence influencing our final judgments will be discussed in the next section.

Figure 9.—Vandalism was regarded as any act damaging to the station or registration forms. In 1961, there were only 3 percent as many acts of vandalism as number of registrations.

## Information from All 1961 Stations

The previous analyses considered only information obtained during interviewing periods on survey trails. In this section, we discuss analyses of information obtained from and about all registration stations for the entire 1961 season. We consider here the potential association with station design of (1) vandalism, (2) the completion and accuracy of registration, and (3) the frequency of nonconstructive comments, or "junk," on registrations. Separate analyses were made for each type of information.

### THE OCCURRENCE OF VANDALISM

Vandalism to unattended equipment exposed to large numbers of people seems inevitable. Special concern seems justifiable only when vandalism occurs at an unusually high rate for the class of equipment.

Presumably, the rate or intensity of vandalism on a station could be influenced by factors associated with the design. For example, a sign wording too forceful or severe to tone could, perhaps, lead to frequent retaliation via vandalism of the station. Consequently, it seemed important to consider vandalism rates in the evaluation of station designs. Careful records were kept of acts of vandalism on each station. A statistical analysis was made to compare rates between designs.

For this study, vandalism was operationally defined as any act damaging to the registration station or associated equipment, including the forms (fig. 9). However, verbal or nonverbal scribbling or "junk" on only one or two forms was not classified as vandalism but was considered in a separate analysis.

The criterion for damage was whether or not the act reduced or destroyed the physical or psychological effectiveness of the station. For example, if all of the forms were removed or

stuffed into the lower section of the card-type box, registration for others was obviously impeded. If the box or signs were scribbled on or defaced in other ways, the aura of the station would be damaged, the station would be less likely to be taken seriously by others, and other acts of vandalism would likely be stimulated.

Acts of vandalism were carefully described and counted each time a station was serviced. At the same time, a count was made of all group registrations occurring since the last servicing. The number of acts of vandalism were, therefore, linked with the number of group registrations during the period the vandalism occurred. (Time periods between servicings were unequal.) Seriousness of the effect on registration of the vandalism acts was thereby automatically weighted roughly; a serious act would be more likely to reduce the number of registrations occurring during the time period and would thereby increase the ratio or number of acts to number of registrations. On the other hand, the more use a trail received, the higher the number of registrations and also the more acts of vandalism that would likely occur. Interaction between number of acts and registrations is apparent either way.

An analysis of covariance was used to remove the effects of varying numbers of registrations on the frequency of vandalism occurring on each treatment and to test the association of vandalism with design. All trails on both study areas were included in one analysis; a separate analysis was also made of the Three Sisters Wilderness Area alone. On both areas, a total of 164 vandalism acts occurred with 5,154 registrations. The number of acts of vandalism and number of registrations occurring by treatments is shown in table 9. The ratios of acts to registrations are also shown in table 9 as an indication of the vandalism rate.

The results of the analyses are summarized in tables 10 and 11. A greater than 5-in-100 chance existed that no significant difference in the number of vandalism acts occurred with different treatments. Interaction between signs and boxes was similarly nonsignificant. Consequently, it is concluded that neither box nor sign designs influenced the rate of vandalism at stations. A decision about best design should be made on the basis of other factors.

Table 9.—Numbers of vandalism acts and registrations and the ratio of acts to registrations, by treatments

| Treatment | Box 1 | | | Box 2 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Acts | Registrations | Ratio | Acts | Registrations | Ratio | Acts | Registrations | Ratio |
| | Number | Number | | Number | Number | | Number | Number | |
| Sign 1 | 35 | 803 | 0.044 | 14 | 440 | 0.032 | 49 | 1,243 | 0.039 |
| Sign 2 | 40 | 1,122 | .036 | 21 | 659 | .032 | 61 | 1,781 | .034 |
| Sign 3 | 32 | 865 | .037 | 22 | 1,265 | .017 | 54 | 2,130 | .025 |
| Total | 107 | 2,790 | .038 | 57 | 2,364 | .024 | 164 | [1]5,154 | .032 |

[1] More registrations than registered groups occur because groups were asked to register both when entering and leaving.

Table 10.—Summary of covariance analysis of vandalism acts: Three Sisters Wilderness Area, 1961

| Source | d. f. | F | $F_{.05}$ | P |
|---|---|---|---|---|
| Adjusted boxes (b) | 1 | <1 | 6.61 | >.05 |
| Adjusted signs (s) | 2 | 2.78 | 5.79 | >.05 |
| Adjusted b X s | 2 | 2.77 | 5.79 | >.05 |
| Within error | 5 | -- | -- | -- |

Table 11.—Summary of covariance analysis of vandalism acts: both study areas 1961

| Source | d. f. | F | $F_{.05}$ | P |
|---|---|---|---|---|
| Adjusted boxes (b) | 1 | 3.54 | 4.84 | >.05 |
| Adjusted signs (s) | 2 | 1.96 | 3.98 | >.05 |
| Adjusted b X s | 2 | 1.30 | 3.98 | >.05 |
| Within error | 11 | -- | -- | -- |

## THE COMPLETION AND ACCURACY OF KEY ITEMS

Analysis of registrant performance on forms was another way of analyzing effectiveness of station designs. Accordingly, registrations were evaluated for completion and prima facie accuracy of key registration items: name and address, date and time of registration, and number of individuals in the group.

The completion-accuracy classes were as follows:

1. All key items seem complete and accurate.
2. No registration or else registration incoherent.
3. Name and/or address too incomplete or inadequate to send mail to the registrant.
4. Date and/or time incomplete or inaccurate.
5. Number of individuals was not stated or was inaccurate.
6. Combination of categories 3 to 5.

Each group with a registration card or interview schedule was assigned to one cell of the two-way (treatment x completion-accuracy class) table. If a group made more than one key omission or error, it was assigned to a "combination" cell.

Chi-square analyses were used to test for significantly different rates of completion and accuracy on different treatments. Observed differences were deemed significant if there was less than a 5-in-100 chance of their occurring because of random sampling errors. The frequency of occurrence of groups in completion-accuracy classes is shown by treatments and blocks in table 12.

The analyses indicated the following:

1. Registration completion and accuracy were not significantly different for different box designs (chi-square: 7.00, 5 d.f., $0.30 > P > 0.20$).

2. Different sign designs did elicit different rates of completion and accuracy of registrations (chi-square: 19.68, 10 d.f., $0.05 > P > 0.02$). More incomprehensible cards, or registration failures, were detected for sign 1 than for either sign 2 or sign 3 (contribution of 11.22 to preceding chi-square of 19.68). Sign 2 elicited the most accurate registration on all key items (chi-square: 14.90, 4 d.f., $0.02 > P > -0.01$).[10]

3. Registration accuracy was not significantly different between geographical blocks of the study areas (chi-square: 16.94, 10 d.f., $0.10 > P > 0.05$).

[10] Chi-square was determined for the three signs times completion-accuracy classes 1, 2, and 3 to 5 combined.

Table 12.—Frequency of groups in completion-accuracy classes by boxes, signs, and blocks

| Item | Completion-accuracy classes | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 Correct | | 2 No registration | | 3 Name-address | | 4 Date-time | | 5 Individuals | | 6 Combination | | Total | |
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| Box 1 | 1,260 | 77 | 49 | 3 | 51 | 3 | 106 | 7 | 68 | 4 | 95 | 6 | 1,629 | 100 |
| Box 2 | 1,416 | 77 | 57 | 3 | 67 | 3 | 121 | 7 | 92 | 5 | 76 | 4 | 1,829 | [1]99 |
| Total | 2,676 | -- | 106 | -- | 118 | -- | 227 | -- | 160 | -- | 171 | -- | 3,458 | -- |
| Sign 1 | 619 | 75 | 40 | 5 | 27 | 3 | 55 | 7 | 44 | 5 | 39 | 5 | 824 | 100 |
| Sign 2 | 894 | 80 | 28 | 2 | 31 | 3 | 71 | 6 | 52 | 5 | 47 | 4 | 1,123 | 100 |
| Sign 3 | 1,163 | 77 | 38 | 2 | 60 | 4 | 101 | 7 | 64 | 4 | 85 | 6 | 1,511 | 100 |
| Total | 2,676 | -- | 106 | -- | 118 | -- | 227 | -- | 160 | -- | 171 | -- | 3,458 | -- |
| Block I | 1,134 | 75 | 53 | 4 | 50 | 3 | 108 | 7 | 89 | 6 | 75 | 5 | 1,509 | 100 |
| Block II | 1,426 | 79 | 49 | 3 | 66 | 4 | 108 | 6 | 66 | 4 | 89 | 5 | 1,804 | [1]101 |
| Block III | 116 | 80 | 4 | 3 | 2 | 1 | 11 | 8 | 5 | 3 | 7 | 5 | 145 | 100 |
| Total | 2,676 | -- | 106 | -- | 118 | -- | 227 | -- | 160 | -- | 171 | -- | 3,458 | -- |

[1] Failure to total to 100 resulted from rounding errors.

## THE FREQUENCY OF NONCONSTRUCTIVE COMMENTS

Another type of performance on registration forms might also have reflected station design variations—the frequency of occurrence of nonconstructive comments, or "junk." "Junk" probably occurs for reasons similar to those causing vandalism.

Single, torn forms were also classified with nonconstructive comments if indicative of irritation or a changed mind about registration. "Junk" was classified as follows:

1. None
2. Nonsensical lines
3. Sensical but innocuous
4. Vulgar; lewd
5. Form torn as result of irritation or a changed mind about registration (usually shredded after completion of several items).

Each registered group was classified and assigned to one cell in two-way tables (treatment x "junk" class). Chi-square analyses were made of the tables. Observed differences were deemed significant if there was less than a 5-in-100 chance of their occurring because of random sampling errors. The frequency of nonconstructive comments is shown in table 13.

The chief conclusions from the analyses are as follows:

1. About as much "junk" occurred with one type of box as the other (chi-square: 5.51, 3 d.f., $0.20 > P > 0.10$).
2. Signs 1 and 3, the signs without reasons for registering, elicited more nonsense and innocuous "junk" than sign 2 (chi-square: 9.23, 3 d.f., $0.05 > P > 0.02$).

The following tendencies are also apparent, although they are either not testable or not significant at the 5-percent level:

1. Sign 3 tended to elicit more "junk" than sign 2 but less than sign 1.
2. Block III tended to elicit more nonsense and innocuous "junk" than blocks I and II.

Vulgar comments, lewd comments, and torn forms resulting from irritation or changed minds about registration occurred with less than 1 percent of registrations. These types of "junk" appeared about as frequently on one treatment and block as others. The general infrequency of all types of nonconstructive comments are further indication of the willingness of trail users to cooperate at registration stations. Nonconstructive comments appeared on only 4 percent of the group registrations.

The mildly toned ("please") sign elicited more "junk" than the other signs, possibly because it was not as commanding of respect. The firmly toned ("must") sign which stated no reasons for registering elicited less "junk" than the mildly toned sign but more than the sign that was firmly toned but also provided reasons for registering.

Table 13.—Frequency of nonconstructive comments ("junk") on group registration cards, by boxes, signs, and blocks

| Item | Classes of nonconstructive comments | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 None | | 2 Nonsense | | 3 Innocuous | | 4 - 5 Severe | | Total | |
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| Box 1 | 1,571 | 96 | 20 | 1 | 31 | 2 | 7 | 0.4 | 1,629 | 99 |
| Box 2 | 1,746 | 95 | 20 | 1 | 57 | 3 | 6 | .3 | 1,829 | 99 |
| Total | 3,317 | -- | 40 | -- | 88 | -- | 13 | -- | 3,458 | -- |
| Sign 1 | 779 | 95 | 14 | 2 | 27 | 3 | 4 | .5 | 824 | 100 |
| Sign 2 | 1,093 | 97 | 7 | 1 | 19 | 2 | 4 | .4 | 1,123 | 99 |
| Sign 3 | 1,445 | 96 | 19 | 1 | 42 | 3 | 5 | .3 | 1,511 | 100 |
| Total | 3,317 | -- | 40 | -- | 88 | -- | 13 | -- | 3,458 | -- |
| Block I | 1,439 | 95 | 20 | 1 | 45 | 3 | 5 | .3 | 1,509 | 99 |
| Block II | 1,745 | 97 | 17 | 1 | 35 | 2 | 7 | .4 | 1,804 | 100 |
| Block III | 133 | 92 | 3 | 2 | 8 | 6 | 1 | .7 | 145 | 100 |
| Total | 3,317 | -- | 40 | -- | 88 | -- | 13 | -- | 3,458 | -- |

SUMMARY OF CONCLUSIONS

The three foregoing sets of analyses contributed the following to our accumulated evidence on effectiveness of registration station designs:

1. Vandalism was not associated with the specific designs of either signs or boxes.
2. Degree of completion and accuracy of key registration items was associated with designs of signs but not of boxes. The firmly toned sign which provided reasons for registering (sign 2) was the most effective. The mildly toned sign (sign 1) yielded the poorest responses, and the most firmly toned sign (sign 3) was intermediate in effectiveness.
3. The firmly toned sign with reasons (sign 2) was the least productive of nonconstructive comments, or "junk," on registration forms; the mildly toned sign (sign 1) elicited the most.
4. In general, the vandalism rate on stations was 3.2 acts per 100 registrations, a figure we judged to be quite tolerably low.
5. Although numerous omissions and errors occurred on registration forms, most registrants seemed to answer the form items willingly. (Improvements in form design might have improved response to specific items.)
6. "Junk" occurred on but 4 percent of the registrations, and a mere 13 of 3,458 registrations indicated hostility via vulgar or lewd comments or a form torn after a person had begun to register.

## Discussion of the 1961 Statistical Analyses

The statistical analyses in 1961 represent four different types of systematic observations of differences in response occurring at registration stations. Probability statements based on standard statistical techniques were made about these observations. These probability statements help to estimate the chances of our overall evaluation being correct: they yielded evidence to help make decisions. Evaluating registration box and sign design on the basis of these four separate approaches greatly increased the confidence in our available evidence. At this point some general conclusions are possible.

The book-type box seemed to be slightly better than the card-type box for obtaining number of group visits and individual visits to the two study areas. Apparently, the easily perused books did represent an attraction not quite as apparent with the more secretive card-type box. It is important to realize, though, that both types of boxes obtained a generally satisfactory response. Of the 94 groups interviewed, 82 percent of the groups exposed to the book-type box and 74 percent of the groups exposed to the card-type box were registered.

The evidence for differences between signs also accumulated in a consistent way but, perhaps, with some disturbance of the traditional conceptions of "good" sign wording. The somewhat sketchy evidence from the interview sample survey for the superiority of the more firmly worded signs was enhanced by analysis of the performance of trail users who did stop at the stations. Although sign tone apparently did not differentially influence the number of groups that stopped to register, it did seem to influence their performance after stopping. More persons registering at the mildly soliciting signs failed to complete all the key items or to complete them accurately; more innocuous nonconstructive comments also appeared. Of the two more firmly worded signs, the one that provided reasons for registering resulted in fewer errors and less "junk."

In none of the analyses was the mild sign better than either of the more firmly worded signs. In most of the analyses, it was clearly inferior. Of the two signs which firmly stated that "all parties must register," the one which followed with reasons for registering produced the best results.

In sum, the weight of the evidence of 1961 indicated that one box design was about as effective as the other. The choice of box type (and the system of form handling represented by it) could reasonably be based on factors other than effectiveness in obtaining satisfactory

response. However, sign design did seem to affect responses at stations—the firmly toned sign with reasons for registering being most effective. Apparently, the best public response and respect at unmanned registration stations, as perhaps in other situations requesting public cooperation, is obtained not by being meek but rather by more adequately fulfilling the role expected by the public of its "forest rangers," that is, by being firm though reasonable.

## Effectiveness of 1962 Design Modifications

The registration station design was modified in 1962 on the basis of 1961 tests. (These modifications were described on page 13.) The design modifications were evaluated by comparing 1962 sampled response with that in 1961 on all designs except the worst one (sign 1, box 1). Comparisons of groups and individuals registered in hiking and riding groups are shown in tables 14 and 15. The 1962 data does not include any interviews with pack-station groups.

Chi-square analyses of data on number of groups registered were made to determine if differences between years could be considered

Table 14.—Registration rate of sampled hiking and riding groups, by year

| | Item | Hiking | Riding | Total |
|---|---|---|---|---|
| 1961 | Actal number | 65 | [1]16 | 81 |
| | Registered number | 62 | 6 | 68 |
| | Percent registered | 95.4 | 37.5 | 84.0 |
| 1962 | Actual number | 135 | 11 | 146 |
| | Registered number | 106 | 4 | 110 |
| | Percent registered | 78.5 | 36.4 | 75.3 |

[1] Includes three parties totaling eight persons riding on or in a motorcycle, two trail scooters, and a jeep.

Table 15.—Accuracy of the number of individuals registered in sampled hiking and riding groups, by year

| | Item | Hiking | Riding | Total |
|---|---|---|---|---|
| 1961 | Actual number | 252 | [1]65 | 317 |
| | Registered number | 198 | 39 | 237 |
| | Percent registered | 78.6 | 60.0 | 74.8 |
| 1962 | Actual number | 523 | 43 | 566 |
| | Registered number | 399 | 17 | 416 |
| | Percent registered | 76.3 | 39.5 | 73.5 |

[1] Includes three parties totaling eight persons riding on or in a motorcycle, two trail scooters, and a jeep.

significant, allowing a 5-in-100 or less chance for random sampling errors. The data on number of individuals registered were not suitable for chi-square analysis because of correlation between groups registered and numbers of individuals registered by group leaders.

The difference in total number of groups registered is not significantly different between 1961 and 1962 (chi-square: 1.80, 1 d.f., $0.20 > P > 0.10$). Although it appears from percentage comparisons that response in 1962 was not quite as good as 1961, the overall percentage difference could have occurred more than 5 in 100 times merely by chance. However, a chi-square analysis of registration rate of hiker groups indicated a significant difference between years; hiker-group responses in 1962 were poorer than in 1961 (chi-square: 8.07, 1 d.f., $0.01 > P > 0.001$). There was obviously no difference in registration rate of rider groups between years.

In an inspection of the number of individuals registered in groups, it seemed apparent that the differences in total sampled response and hiker-group response between years were clearly not significant. The large difference in percent of riders registered was directly the result of one large group registering and was treated as a chance occurrence.

Why was group registration response from hiking parties seemingly poorer in 1962? An examination of table 16 provided a clue. From the table, it appeared that fewer single-person parties registered in 1962 than 1961. Analysis using a Fisher exact probability test[11] confirmed this at the 5-percent level. It was also apparent that in 1961 more parties, especially large ones, were registered by more than one person (although number of individuals registered by each registrant did not usually include all members of the party). Consequently, the higher percentage of groups registered in 1961 resulted from (1) registration by a larger proportion of very small parties and (2) multiple registration by three large parties. These facts explain why the percentage of individuals registered was

[11] See Siegel, p. 96 (footnote 8).

about the same from one year to the next for hikers, even though the percentage of groups registering changed. The lower response in 1962 seemed most attributable to the lower rate of multiple registration by large groups—an improvement in quality of response which may have resulted from increased clarity in sign wording in 1962. We were unable to explain why the significantly lower rate of response by single-person parties occurred. Fortunately, the poorer response by single-person parties did not have noticeable numerical effect on use estimates made from registration information.[12]

Our major conclusions from the statistical analyses about station design are:

1. The design of signs eliciting prescribed response was a significant element influencing the effectiveness of unmanned registration stations. A direct, firmly toned sign that stated a reasonable purpose for registering was most effective.
2. A box design permitting public inspection of prior registrations is not much more or less effective than one which keeps registrations from public view, although the former design may have attracted a slightly higher rate of registration. A conspicuous map mounted with the boxes designed to keep registrations private increased the apparent attraction of this box design.
3. Hiker groups registered at a much higher rate than horseback groups; however, the registration rate stability and number of horseback registrations was adequate to permit estimates of actual horseback visits, as well as hiker visits, from registrations.

In the next sections, we discuss our other observations on the design of stations and also consider other factors relevant to their use.

[12] Use estimates will be presented in a later report.

Table 16.—Registration rate of sampled hiker groups, by party size for 1961 and 1962[1]

| Party size | 1962 | | | 1961 | | |
|---|---|---|---|---|---|---|
| | Actual number of groups | Groups registered | Percent registered | Actual number of groups | Groups registered | Percent registered |
| 1 | 4 | 4 | 100.0 | 10 | 3 | 30.00 |
| 2 | 22 | 17 | 77.3 | 39 | 30 | 76.92 |
| 3 | 14 | 10 | 71.4 | 21 | 18 | 85.71 |
| 4 | 10 | 10 | 100.0 | 28 | [2]23 | 82.14 |
| 5-7 | 9 | [2]10 | 111.1 | 29 | 26 | 89.66 |
| 8+ | 6 | [2]11 | 183.3 | 8 | 6 | 75.00 |
| Total | 65 | 62 | -- | 135 | 106 | -- |

[1] Data for the same groups as reported in table 14.
[2] One or more groups of this party size was registered by more than one group member.

# Observations of Design, Location, and System of Use

The previous chapter presented formal statistical comparisons of some station design variations. In this chapter, we discuss our nonstatistical observations of design, location, and system for use of stations.

## General Station Design

The two features of station design (box type and sign tone) analyzed statistically were not the only features of importance. Other features included general sign design, box construction, and accessories to facilitate registration.

Toward the end of the 1961 season and after, we conversed with trail users for their impressions of the station design. These conversations reinforced our season-long observations. Although several trail users we talked to had passed various designs of the stations, usually only the variation in design of the box was remembered. The reason was readily discernible; after the first encounter with a station, the sign usually was not consciously read again.

We wished only one person to register for each party. It was somewhat difficult to convey the idea of "party" and "group" being any party of one or more persons. We deliberately used both words "party" and "group" on the signs in 1961, hopefully providing a general enough stimulus to convey the idea one way or the other; this scheme seemed to work well. Difficulties of interpretation arose largely from the double term "group leader." This seemed to imply a formally structured group. We depended on the tendency in small, informal groups for some person to step forward in the role of leader when a situation required one. Although this usually happened, confusion was apparent even in some well-structured family groups who were not sure if they were a "group" as implied by the term "group leader." This problem of communicating who and how many were to register from each group was resolved with apparent success in 1962. The instructions about "who and how many" read simply, "One person from each party register . . . "

All our other experience in the study also indicated that sign wording was critical in providing (1) motivation and (2) explicit, clear instructions. Because many persons merely glanced at the sign again after the first time, extreme brevity of wording seemed necessary to make any impact on repeat visitors. This need for brevity increased the problem of sign wording and made it the chief problem of station design.

We observed that many trail users seemed to become absorbed in their thoughts while traveling and often looked only at the trail when they were hiking. Inconspicuous signs were frequently not seen. Consequently, although registration stations should be harmonious with the wilderness environment, at least the signs must be conspicuous enough to attract the attention of trail users.

The maps mounted above registration boxes in 1962 were observed to be highly popular. Aside from the attraction they lent to stations, the service they provided the public seemed well appreciated. We used the best maps of the local area obtainable at a scale of either one-half inch or 1 inch to the mile.

Maps were securely fastened with a staple gun to backing boards by spacing staples about 3 inches apart across the surface of the map. Because maps were laminated in 10-mil plastic, attempts to remove them usually would crack them up—a factor which seemed to discourage most tentative removal attempts. However, if the staples used were not long enough to set

tightly, some persons would eventually pry them all out to obtain the map.

Few maps were stolen or damaged during the summer season. A somewhat higher loss rate occurred during the hunting season. Perhaps rate of map loss at stations could be reduced by making high quality maps more readily available to recreationists, especially hunters, who need one with them when in the backcountry.[13]

After stopping at stations, trail users were cogently instructed about registration steps by small aluminum, embossed signs on the boxes and by brief instructions on the cards. These were in lieu of a separate board or list of consolidated instructions. These brief instructions, at the places needed as a person went through the tasks, produced good results.

In 1961, two ballpoint pens were chained to each station and a pencil was placed inside each box to facilitate registration. Initially, vandalism of pens was expected to be a sizable problem; it was not. In 1962, only one pen was chained to each station in addition to the pencil inside; this system seemed as adequate as in 1961. Pens and pencils were difficult to keep on some stations, but not on most. The rate of loss seemed directly related to the differences in characteristics of the users on different trails, rather than to the volume of use per se.

In preliminary tests of writability, the ballpoint pens were clearly superior to pencils for writing on wet forms;[14] consequently, pens were the preferred writing instrument. The objective of having both pen and pencil was to have something left if one was stolen. Contrary to expectation, the pencil was often taken and the pen left, perhaps because registrants forgot that the pencil belonged at the station.[15]

During very wet weather, it was discovered that neither the pens nor pencils would write on the wet forms. Failure of both instruments resulted in a number of frustrated registrants, as seen by the attempted registrations. In 1962, the problem was solved by providing a special pencil—an ink or copying pencil. These pencils resulted in readable, though messy, registrations in extremely wet weather. Pens were still provided because, unless weather was extremely wet, resulting registrations were generally much more readable.

Although the small plastic calendars mounted under box lids were visible when boxes were opened, they frequently were not noticed and gross errors in dates occurred. These errors were more frequent with card-type boxes which had lids that would not open fully. In 1962, calendars were placed on top of the lids of the card-type boxes. Wallet-size plastic calendars were large enough to be readily seen when on top, but not so large as to detract from the general neat appearance of the station.

The card-type boxes were considerably easier to construct and mount securely than the book-type boxes. Forms were easier to load into the boxes and to handle during registration and when coding for analysis. Card-type boxes of a given bulk held forms for several times more potential registrations than did book-type boxes.[16]

## Location of Stations

Stations were located in cordon fashion on the perimeter of the study areas. Field experience with station installation revealed some pragmatic aspects of macro- and microlocation. As the terms are used here, macrolocation would be placement relative to an area as a whole, and microlocation, relative to any one trail.

### MACROLOCATION

When we considered a system of stations that would cover all or most use on an area, two

[13] Maps of the study areas were not readily available. If available at all, they were usually at ranger or guard stations, which often were either far from the areas or unattended because the forest guards were working away from stations. Availability would be improved by (1) providing resorts and other local service establishments with maps for distribution and (2) placing maps in "take one" boxes at principal trailheads, guard stations, and campgrounds around a backcountry or wilderness area.

[14] Forms got wet when box lids were open to register.

[15] On the other hand, stations also accumulated an odd assortment of pencils left by registrants.

[16] We discovered this in lab tests of box-holding capacity. We assumed a looseleaf book arrangement essential for registration ease at book-type stations.

basic approaches seemed possible: (1) location of stations at trail junctions and other significant places on the interior of an area and (2) location of stations at trailheads on the perimeter of an area. Which approach was used seemed likely to influence both registration response and administrative cost of using stations. Although we tested the stations as located only on the perimeters of areas, it seemed, on the one hand, that interior locations would have but two advantages:

1. If stations were placed at natural rest places, momentum would be less of an obstacle to registration. Psychological momentum, that is, the motive force that keeps a body in motion toward a goal, is greatest with pack and saddle stock users. When a string of horses starts up a trail, both the people and the stock are set to go. The obstacle to registration is increased by the likelihood of stock milling around and getting twisted in lead ropes while someone registers.
2. Less vandalism would likely occur with interior locations because of removal from casual persons attracted to stations from roads or roadside campgrounds.

On the other hand, from our observations, perimeter location of stations seemed to have the following advantages:

1. Trail users were exposed to a station only when entering or leaving an area; confusion about when they were to register was minimal.
2. Registration was identified with actual entry into the backcountry and thereby gained symbolic significance.
3. All users of an area could be encountered more easily: persons going into an area only a short distance were covered; recreationists using an area were more likely to still be on a trail at the perimeter where the stations were than further in where many persons left trails.
4. Fewer stations were necessary to cover all areas of travel adequately.
5. Stations could be constructed with somewhat less concern for the rustic appearance that is desirable within areas. As a result, stations could be made conspicuous enough to be noticed by all travelers, and costs of construction were less than could be expected for construction from rustic materials.
6. Costs of regularly maintaining stations and retrieving data were lower because of less travel time than would have been necessary for interior stations.
7. Trail users recognized stations to be a means to locate them more readily in case of emergency.

The advantages of interior locations are, in converse, disadvantages of perimeter location. To minimize these disadvantages of perimeter location, registration stations were placed (1) at points where horses were saddled, packed, and/or mounted and (2) slightly up the trail from the trailheads where vandalism seemed a problem. In sum, the advantages of perimeter location of stations seemed to greatly outweigh those of interior location.

The principal obstacle to getting complete station coverage of the study areas was finding all access trails. Many trails used by recreationists were not officially on the Forest Service trail system. Some of these had been on the system in the past but were abandoned; some others had never been officially recognized or maintained. Some of these unofficial trails were very popular. These unofficial trails had to be covered if all use was to be censused. In some instances, shortcut routes bypassed principal trailheads; these also had to be adequately covered by registration stations.

Although Ranger District personnel had been contacted prior to the study, few of them seemed to know anything about the official trail system, and information about unofficial trails was almost nonexistent. We concluded that it would have been quite helpful to seek out recreationists in the local area who were highly familiar with the trails on an area of interest. In finding trails, a careful study of old maps of the area was as important as study of most recent ones. Aerial photos might have been helpful on some open parts of the areas. In addition, a careful

search of the perimeter for clues to additional access trails was necessary.

Coverage of nontrail[17] use was only a slight problem on the study areas. Steep topography, dense vegetation, and the wish to leave the perimeter environment quickly, kept almost all users of the areas on or along trails for at least a short distance into the area. But along the short stretch where the perimeter terrain was highly scenic, gentle, and with open or sparse vegetation, many recreationists did not use available trails, and effective coverage of use with stations became difficult. A heavy scattering of stations to cover most frequently traveled routes, natural constrictions in the routes, or usual parking spots is necessary where this latter type of terrain is to be covered.

### MICROLOCATION

Wherever possible, registration stations were mounted on available stumps or trees. Stations mounted this way presented a neat and more rustic appearance than those mounted on posts. Mounting with appropriate backing boards and lag screws facilitated easy removal of stations without damage to either station equipment or trees. Very light brushing out was done when necessary to permit easy sighting and use of stations. When stumps or trees were not available at appropriate trailhead locations, a large post was firmly set. This latter procedure was sometimes very difficult in thin, rocky soil; nonetheless, a properly located post was preferable to a stump or tree in a poor place.

Not all trails were used by horseback riders, but for those that were, microlocation of stations was somewhat critical. To obtain maximum cooperation of horsemen, stations should be readily accessible to them before they mount for their trip. At the least, stations on horse-used trails should be directly at the trailhead, and supplementary stations may be necessary at other mounting points and shortcuts. Where groups from pack stations, or riding stables, use trails on an area, pack-station records might be requested that would provide needed information about horse parties.

Where horse use of a trail was not a factor to consider, an effective station location was much easier to find. Station location at the trailhead was ideal for hikers, primarily because the station became a symbol of entry into the backcountry and, therefore, a significant part of the trip, as was evidenced by group pictures being taken of the registration process. Occasionally it was necessary to retreat from vandals and move the station up the trail a short distance, out of view of casual road hikers or bored children from campgrounds adjacent to trailheads. But whether at the trailhead or up the trail a short distance, stations should be readily visible to a hiker as he looks up the trail without necessitating his looking to one side.

Stations along steep sections of trail discourage registration. Stations should be located at places where other members of the party, as spread out along the trail, may stop and stand easily while one party member registers. Locations should also permit registrants to stand conveniently while registering.

## Methods of Station Use

It was decided that only one person per group should register. Having only one person per group register would obviously place the least burden of time and inconvenience on a group, and it would minimize "pileups" of the trail users at the stations. However, followup research on the group or its members would depend upon the willingness and ability of the group leader to provide information about group members when he was contacted later. This was tested in a separate substudy, and it was found that a 60-percent response was obtained to mail requests for names and addresses of party members.[18]

As requested by the signs, most groups were registered by only one person; however, exceptions did occur and were detected in the

[17] Any beaten path defined by human use was a "trail" for study purposes. Travel into an area cross-country from an access road, i.e., off any previously defined path, was called dispersed, or nontrail use.

[18] One followup request followed the initial request.

process of the interview sample survey and coding of registration data. The overall bias on number of calculated groups was, therefore, easily removed.

In 1961, parties were asked to register both when entering and leaving so that (1) an accurate record of actual length of visit and (2) frequency that trail users entered on one trail and left on another could be determined. Many persons were not willing to be twice troubled with complete registration on the same trip. Book registrants resolved the issue somewhat by writing "out," "leaving now," or some such indication on the entry registration form. But the procedure seemed to require more of registrants than was justified by the slight increase in quality of data obtained by the method. Also, data handling time and cost were greatly increased by the double-registration method. Accordingly, in 1962, parties were only asked to register when entering. Length-of-visit and destination information were asked directly of registrants. The 1962 method seemed to provide adequate information without so much trouble to both registrant and data analyst.

## Conclusions

Major conclusions resulting from these observations are summarized as follows:

1. In addition to the effect apparent from the tone of station signs, sign wording was critical for providing positive motivation and cogent instructions for registering.
2. "Once read, never read again closely" expresses a response of many persons toward signs. We suspect that after the first reading, the impact gained in a glance must be sufficient to recall the sign's detailed message. Consequently, distractions unnecessary to the sign's intent should be avoided, and "register" should be the most apparent word at a glance.
3. Stations must be kept harmonious with the forest environment, but they must also be conspicuously attractive if they are to be noticed and used.
4. Maps above registration boxes seemed to help attract visitors to the station. This service seemed much appreciated.
5. Card-type boxes were more convenient administratively than book-type boxes.
6. Perimeter location of stations seemed overwhelmingly superior to interior location from the criteria of effective coverage of all area use, administrative efficiency, and other factors.
7. Registration stations were more difficult to place and less effective in covering use where the area perimeter was scenic, sparsely vegetated, and gentle in terrain.
8. Discovery of all access trails into a moderately large backcountry area requires considerable ingenuity and effort, but is important in initial studies if coverage is to be complete enough to derive sufficiently accurate use estimates for the area.
9. On trails that receive horse use, stations should be placed where riders can register before mounting.
10. Best cooperation of visitors and minimum data handling can be obtained without important loss of information if registration is requested but once per group and per visit.

# Study Administration Costs

The administrative time and costs of using a system of unmanned registration stations will vary with the size of an area, number of access trails, accessibility to trailheads, intensity of trail use, size of interview sample needed to obtain data accuracy desired, and methods of data analysis. Consequently, the specific total time and cost estimates will be highly variable from place to place.

Detailed advanced planning is necessary (1) to obtain necessary Budget Bureau approval[19] of the registration forms and interview schedule, (2) to make most effective use of the short season common with most high-country areas, and (3) to schedule necessary data processing services.

Some additional comments are offered as assistance for future studies.

## Installation, Maintenance, and Survey Costs

Registration stations cost a total of about $10 each before installation. Commercially bid and manufactured boxes cost about $7.50, and about $2.50 was needed for signs and accessories. Commercially printed forms were nominal in cost and could be serially numbered during printing or by IBM facilities.

Installation of each station—selection of microlocation, brushing out, mounting of station, loading forms, and preparing form record of installation—required a modal time of 45 minutes per station (fig. 10). If a post was needed for station mounting, the time of installation was considerably increased.

The need for servicing and maintenance of stations varied with intensity of trail use. During the recreation season, stations should be checked and serviced at least once a month. Trails with 1,000 or more visits per season need servicing every 2 to 3 weeks. Form handling, service-record preparation, and minor repair or replacement work required about 15 minutes per station per service call excluding travel time.

Figure 10.—Installation of stations required a modal time of 45 minutes each.

[19] As required under the Federal Reports Act of 1942 for most situations in which 10 or more persons are asked for the same information.

Travel time to install and maintain stations was highly variable, depending on access road location and conditions. For a large area with many stations and difficult access, helicopter transportation should be considered for feasibility in "making the rounds."

Stations may be left in place over winter without serious deterioration if strong enough to support the snow load and if constructed of thoroughly waterproof materials. Signs of high quality enamel on tempered hardboard and boxes made of marine plywood well sized before staining held up well. Restaining of boxes in the spring of each year would be desirable and easily done at the trail location.

Cost of equipment, installation, and maintenance of stations seemed entirely reasonable. By comparison with other equipment used to measure trail use, e.g., pneumatic pedestrian traffic counters, unmanned registration stations permit collection of more meaningful data on more trails for a given sum of money.

The interview sample survey necessary for interpreting and estimating use from registration data was the most expensive element in the system employing unmanned registration stations; however, similar surveys are also essential to proper use estimation that employs automatic, mechanical equipment. It is likely, though, that derived estimation factors could be used with a system of stations for 2 or 3 years before user characteristics would change significantly enough to necessitate a new sample survey. As will be described in a future report on survey methods, interviewing costs for a specific area and a given allowable sampling error can be estimated with considerable precision.

## Data Handling Methods and Costs

Data handling and analysis were significant cost items in these studies and would be for most studies on areas with about 3,000 or more visits a year. For this volume of data or more, an edge-punch card system or automatic data processing seems essential. But the complexity of information desired from the data will largely determine the most feasible system.

Prior to developing the coding scheme, preliminary data objectives should be clearly stated, but these must remain flexible if fullest benefit is to be made of insights about interpretation of data gained during its collection. From our experience, it seems advisable to have the coding scheme devised at the beginning of a field season so that coding can start and keep pace with collection of station data.

In addition to coding and machine programing, the card punching, machine analyses, and tabulation for about 4,000 registered groups cost us about $1,000 for a moderately complex analysis. Card punching alone cost approximately $300.

It is recommended that in future studies an edge-punch card or similar semi-manual system be tested. With such a system, it might be possible to print registration forms directly on the special data processing cards and to use the field interviewers' spare time to code these cards directly in the field. With such a system, it might be possible to shortcut the coding-punching operations, thereby saving funds, reducing delay in reporting use, and keeping interviewers fully occupied.

# Summary and General Conclusions

A 2-year test of effectiveness of unmanned registration stations was conducted on two wilderness-type areas in Oregon. Unmanned registration stations appear to have considerable potential for obtaining information about wilderness use. Such information is needed for immediate management purposes and for additional research helpful to allocation of land, the shaping of management goals, and long-range planning.

The major components of stations were the sign announcing the station and providing general instructions, the box containing registration forms, the forms for registration, and accessories including pen and calendar.

This first report on the study evaluates and discusses the effective design, location, and prescribed system of use of registration stations on wilderness areas. Additional reports to follow will describe interview survey sample methods essential to use estimation from stations, biases in "raw" data from stations, and the 1961 and 1962 recreation use on the study areas.

Interview sample surveys of trail users and user responses at stations were used to obtain criteria of the effectiveness of stations. Six station design variations were compared for effectiveness in 1961, and one design was tested in 1962 using statistical techniques. In addition, nonstatistical systematic observations were used to evaluate other factors about design, location, and system of station use.

Detailed conclusions are reported throughout the report. Our general conclusions are as follows:

1. Unmanned registration stations can be used effectively and efficiently to obtain much information from wilderness trail visitors about the objective details of their groups and visits.
2. The average rate of registration was between 70 and 85 percent. Horseback visitors registered at a much lower rate, but in sufficient numbers and at a constant enough rate for adequate use estimation to be possible.
3. The most effective sign wording for attracting, motivating, and instructing potential registrants seemed to be brief, cogent, and firmly toned, with a short reason for registering.
4. A box design permitting public view of completed registrations seemed to attract a slightly higher percentage of trail users, but higher quality registrations tended to be obtained with box designs protecting registrations from perusal. The latter box design was the more convenient to build and mount, it held forms more efficiently, and the forms were easier to handle.
5. Perimeter locations of stations at all trailheads into an area resulted in more effective coverage of area use and higher administrative efficiency than seemed possible with interior locations.
6. Registration stations were least effective for covering area use where the perimeter was scenic, sparsely vegetated, and of gentle terrain.
7. The best system of prescribed registration requested each party to register but once per trip. Only one person per party was to do the job.
8. In total, employment of unmanned registration stations resulted in collection of more meaningful data at less total cost than seemed possible using other equipment, such as automatic pedestrian traffic counters.
9. This system, as well as other systems to measure trail or area use, depends on supplementary application of sound sample survey techniques as a basis for developing use estimates and interpreting information obtained with the unmanned equipment.

# APPENDIX A

## Principal Recognizable Features of Forest Service Wilderness-Type Areas

1. Acreage—

   Wild areas from 5,000 to 99,999 acres.

   Wilderness areas are 100,000 acres or more.

   Primitive areas are 5,000 acres or more.

2. Development—

   Roads are generally excluded except for private roads legally necessary for access to private inholdings, to valid mining claims, or to water development sites.

   Lookout towers and rudimentary campsite developments are permissible.

   Minor water development projects are permitted.

   Primitive and semi-primitive developments are permitted when necessary for protection of camping sites and associated areas.

   Trails are permitted.

3. Equipment restrictions—

   No motor vehicles, either land, air, or water, are permitted, with certain exceptions for administrative or emergency purposes.

   Chainsaws, power generators, and similar motor-driven devices are not permitted except for administrative purposes.

4. Uses—

   Timber cutting is not permitted and usually has never been done on the areas.

   Grazing is permitted where established.

   Prospecting is permitted.

   Water yield is usually a principal concrete value of the areas.

   Recreation and scientific study are encouraged.

# APPENDIX B

## Interview Schedules

1961

Budget Bureae No. 40-6131
Approval expires 6/30/62

FIELD INTERVIEW QUESTIONNAIRE

Wilderness-Use Study

Instructions to interviewer:

1. This form is to be filled out by you. Do not give it to the interviewee to fill out by himself. However, if an interviewee wishes to look at the form, it is permissible for him to do so.
2. Read to the interviewee only the capitalized wording.
3. Count for yourself the number of persons and number of pack and saddle stock.
4. Read the detailed instructions for interviewers.

HELLO. I'M MAKING A SURVEY OF TRAIL USERS. WHICH PERSON IS THE GROUP LEADER? (Go to the designated person).

HELLO. I'M (your name) . I'M WITH THE U.S. FOREST SERVICE. WE'RE MAKING A ROUTINE SURVEY OF TRAIL USERS. INFORMATION YOU GIVE ME WILL HELP THE FOREST SERVICE MEET THE NEED FOR TRAILS AND OTHER FACILITIES IN THIS AREA.

WHERE DO YOU LIVE? _____
(City and State)

HOW DO YOU SPELL YOUR NAME? _____

WHAT IS YOUR ADDRESS IN (name of city)? _____

HOW LONG DO YOU EXPECT TO STAY IN THIS AREA BEFORE ARRIVING BACK AT A ROAD?

- ☐ less than 1 day
- ☐ overnight to 3 days
- ☐ 4 to 7 days
- ☐ 8 days to 2 weeks
- ☐ over 2 weeks

HAVE YOU TRAVELED TRAILS IN THIS AREA BEFORE? ☐ no ☐ yes

(if "yes", ask) THIS YEAR? ☐ no ☐ yes

THANK YOU VERY MUCH FOR YOUR HELP. HAVE A GOOD TRIP!

Total number of persons in group? ☐

Total number of pack and saddle stock? ☐

(check one) ☐ walking ☐ riding horses ☐ other _____ (specify)

Interview date _____ Time ____ ☐ a.m. ☐ p.m.

Trail No. _____.

Interviewer's initials _____.

Budget Bur.No. 40-6134A
Approval expires 6/30/63

1962

FIELD INTERVIEW QUESTIONNAIRE
(Revised Form)

Wilderness-use Study Form A (Entering)

INTERVIEWER: Only you are to fill this out! Read detailed instructions before beginning. Questions 1-11 refer to interviewee only.

HELLO. I'M MAKING A SURVEY OF TRAIL USERS. WHICH PERSON IS THE GROUP LEADER? (Go to designated person)

I'M (interviewer's name). I'M WITH THE U.S. FOREST SERVICE. I'M GATHERING INFORMATION THAT WILL HELP THE FOREST SERVICE MEET YOUR CHANGING NEEDS FOR TRAILS AND OTHER FACILITIES IN THE AREA.

1. (A) HAVE YOU EVER TRAVELLED TRAILS IN THIS AREA BEFORE?
☐Yes ☐No (if no, skip to question 3)
(if yes, ask):

(B) EARLIER THIS YEAR? ☐No (if no, skip to question 2)
☐Yes
(if yes, ask):

(C) WHICH TRAILS WERE YOU ON THIS YEAR? _____

2. ABOUT HOW OFTEN HAVE YOU USED TRAILS IN THIS AREA PREVIOUS TO THIS YEAR? (Probe for both years and times)

| Years: | Times: |
|---|---|
| ☐1 year | ☐1 time |
| ☐2 years | ☐2 times |
| ☐3-5 years | ☐3-5 times |
| ☐6-10 years | ☐6-10 times |
| ☐More than 10 years | ☐More than 10 times |

3. HOW DID YOU HAPPEN TO PICK THIS PARTICULAR AREA FOR YOUR TRIP RATHER THAN SOME OTHER?
☐Friends told us about it ☐Been here before and liked it
☐Close to home ☐Other: _____
☐Found it by chance

4. (A) ARE YOU A MEMBER OF AN OUTDOOR CLUB?
☐Yes ☐No (if no, skip to question 5)
(if yes, ask):

(B) WHICH,ONE? _____

(C) IS THIS TRIP SPONSORED BY YOUR CLUB?
☐Yes ☐No

5. HOW LONG DO YOU PLAN TO STAY IN THE AREA BEFORE GETTING BACK TO THE ROAD?
☐Less than 1 day ☐8 days to 2 weeks
☐Overnight to 3 days ☐Over 2 weeks
☐4-7 days

6. HOW MANY MILES DO YOU PLAN TO GO INTO THE AREA THIS TIME?
   ☐Less than 1 mile ☐4-10 miles
   ☐1 mile to 3 miles ☐More than 10 miles

7. WHERE IN THE AREA DO YOU PLAN TO GO? _____

8. WHERE IS YOUR HOME? (city & state) _____

9. WHAT IS YOUR ADDRESS IN (name of city)? _____

10. HOW DO YOU SPELL YOUR NAME? _____

11. WHAT IS YOUR OCCUPATION? _____

12. (A) BY WHAT MEANS OF TRAVEL DID YOU ARRIVE AT THE BEGINNING OF THIS TRAIL?
    ☐Motor vehicle
    (if motor vehicle, ask):
    ☐Other(what?):_____
    (skip to question 13)

    (B) DID YOUR PARTY ARRIVE IN MORE THAN ONE VEHICLE?
    ☐Yes
    (if yes, ask):
    ☐No
    (if no, ask):

    (C) (1) WHAT ARE THE NAMES OF THE OWNERS?
    ☐Registrant owns one
    ☐Other owners(names):
    _____
    _____

    (2) DOES THE VEHICLE BELONG TO YOU?
    ☐No ☐Yes (skip to 12)

    (3) WHAT IS THE OWNER'S NAME?
    _____

13. WHAT IS THE MAJOR PURPOSE OF THIS TRIP?
    ☐Recreation(what?):_____ ☐Work(what?): _____

14. DO YOU HAVE ANY FURTHER COMMENTS ABOUT THIS AREA? (Write key words to remarks at time of interview. Detail remarks after interview).

THANK YOU FOR YOUR HELP. HAVE A GOOD TRIP.

15.___Total number of persons in group
16.___Total number of pack stock
17.___Total number of riding stock

18. Recreation equipment visible:_____
_____

19. Age and sex distribution of group:
____females older than 12
____females younger than 12
____males older than 12
____males younger than 12

Interview date:_____ Interview time:_____ a.m. p.m. Trail Number:_____

Trail Name: _____ Interviewer's initials:_____

Interviewer: Make additional comments on back!

1962

FIELD INTERVIEW QUESTIONNAIRE
(Revised Form)

Wilderness-use Study Form B (Leaving)

INTERVIEWER: Only you are to fill this out! Read detailed instructions before beginning. Questions 1-11 refer to interviewee only.

HELLO. I'M MAKING A SURVEY OF TRAIL USERS. WHICH PERSON IS THE GROUP LEADER? (Go to designated person)

I'M (interviewer's name) . I'M WITH THE U.S. FOREST SERVICE. I'M GATHERING INFORMATION THAT WILL HELP THE FOREST SERVICE MEET YOUR CHANGING NEEDS FOR TRAILS AND OTHER FACILITIES IN THE AREA.

1. (A) HAVE YOU EVER TRAVELLED TRAILS IN THIS AREA BEFORE THIS TRIP?
☐Yes ☐No (if no, skip to question 3)
(if yes, ask):

(B) EARLIER THIS YEAR?
☐Yes ☐No (if no, skip to question 2)
(if yes, ask):

(C) WHICH TRAILS WERE YOU ON THIS YEAR BEFORE THIS TRIP? _____

_____

2. ABOUT HOW OFTEN HAVE YOU USED THE TRAILS IN THIS AREA PREVIOUS TO THIS YEAR? (Probe for both years and times)

| Years: | Times: |
|---|---|
| ☐1 year | ☐1 time |
| ☐2 years | ☐2 times |
| ☐3-5 years | ☐3-5 times |
| ☐6-10 years | ☐6-10 times |
| ☐More than 10 years | ☐More than 10 times |

3. HOW DID YOU HAPPEN TO PICK THIS PARTICULAR AREA FOR YOUR TRIP RATHER THAN SOME OTHER?
☐Friends told us about it ☐Been here before and liked it
☐Close to home ☐Other: _____
☐Found it by chance

4. (A) ARE YOU A MEMBER OF AN OUTDOOR CLUB?
☐Yes ☐No (if no, skip to question 5)
(if yes, ask):

(B) WHICH ONE? _____

(C) IS THIS TRIP SPONSORED BY YOUR CLUB?
☐Yes ☐No

5. HOW LONG HAVE YOU BEEN IN THE AREA AWAY FROM ROADS?
☐Less than 1 day ☐8 days to 2 weeks
☐Overnight to 3 days ☐Over 2 weeks
☐4-7 days

FIELD INTERVIEW QUESTIONNAIRE--Form B--page 2

6. (A) WHERE DID YOU ENTER THIS AREA? (probe) _____

(B) ARE ALL MEMBERS OF YOUR STARTING PARTY HERE WITH YOU NOW?
☐Yes ☐No. (probe) No. entering: _____

7. WHERE IN THE AREA DID YOU GO? _____

8. WHERE IS YOUR HOME? (city & state) _____

9. WHAT IS YOUR ADDRESS IN (name of city)? _____

10. HOW DO YOU SPELL YOUR NAME? _____

11. WHAT IS YOUR OCCUPATION? _____

12. (A) BY WHAT MEANS OF TRAVEL DID YOU ARRIVE AT THE POINT WHERE YOU ENTERED THIS AREA?
☐Motor vehicle
(if motor vehicle, ask):
☐Other (what?): _____
(Skip to question 13)

(B) DID YOUR PARTY ARRIVE IN MORE THAN ONE VEHICLE?
☐Yes
(if yes, ask):
☐ No
(if no, ask):

(C) (1) WHAT ARE THE NAMES OF THE OWNERS?
☐Registrant owns one
☐Other owners (names):
_____
_____

(2) DOES THE VEHICLE BELONG TO YOU?
☐No
☐Yes
(skip to 12)

(3) WHAT IS THE OWNER'S NAME?
_____

13. WHAT WAS THE MAJOR PURPOSE OF THIS TRIP?
☐Recreation (what?): _____ ☐Work (what?): _____

14. DO YOU HAVE ANY FURTHER COMMENTS ABOUT THIS AREA? (Write key words to remarks at time of interview. Detail remarks after interview).

THANK YOU FOR YOUR HELP. HAVE A GOOD TRIP HOME.

15. ___ Total number of persons in group
16. ___ Total number of pack stock
17. ___ Total number of riding stock.
18. Recreation equipment visible: _____
_____

19. Age and sex distribution of group
___females older than 12
___females younger than 12
___males older than 12
___males younger than 12

Interview date: _____ Interview time: _____ a.m. p.m. Trail Number: _____

Trail Name: _____ Interviewer's initials: _____

Interviewer: Make additional comments on back!

# APPENDIX C

## 1962 Registration Card Designs

REGISTRATION CARD

ONLY ONE person from each group please answer ALL questions.

Your Name: _____

Street/Box: _____

City & State: _____

Date: _____ Time: _____ a.m. p.m.

---

The number of persons in your group
12 years and older? _____
Younger than 12 years? _____

---

Did you arrive at the start of this trail in your own vehicle?
☐ Yes.
☐ No. Name of vehicle owner: _____

---

About how long will you be away from roads on this trip? ___ days (___ hours)

---

How will you travel in the area:
☐ Walking
☐ Riding horses (how many?) _____
☐ Other (what?) _____

How many pack animals? _____

---

The purpose of this trip is:
☐ Recreation (what?) _____
☐ Work (what?) _____

---

How far into the area are you going?
☐ Less than 1 mile
☐ 1 to 3 miles
☐ 4 to 10 miles
☐ More than 10 miles

Destination in area: _____

BUDGET BUREAU NO 40-6235
APPROVAL EXPIRES 6/30/63 No 7114

PACK STATION REGISTRATION CARD

ONE member of each group please answer ALL questions. Put in registration box.

Your Name: _____

Street/Box: _____

City & State: _____

Date: _____ Time: _____ a.m. p.m.

---

The number of persons in your group
12 years and older? _____
Younger than 12 years? _____

---

About how long will you be away from roads on this trip? ____ days (___ hours)

---

How will you travel in the area:
☐ Walking
☐ Riding horses (how many?) _____
☐ Other (what?) _____

How many pack animals? _____

---

The purpose of this trip is:
☐ Recreation (what?) _____
☐ Work (what?) _____

---

How far into the area are you going?
☐ Less than 1 mile
☐ 1 to 3 miles
☐ 4 to 10 miles
☐ More than 10 miles

Destination in area: _____

BUDGET BUREAU NO. 40-6236
APPROVAL EXPIRES 6/30/63 No 11646

# APPENDIX D

# 1961 Interview Sample Survey Analyses Summaries

## Group Registration Errors

The occurrence of errors and the results of the Kruskal-Wallis test[20] are reported in tables 17 to 37. As an example of the ranking prior to the computation of H, ranked error scores of all planned interview groups are shown in table 17 for the analysis of box differences.

1. Analyses of group errors of all planned interview groups:

Table 17.—Ranked group error scores of all planned interview groups by types of box

| Error score | Number of groups ($n$) | Rank score ($R$) | Box 1 (Card type) | | Box 2 (Book type) | |
|---|---|---|---|---|---|---|
| | | | ($n_1$) | ($Rn_1$) | ($n_2$) | ($Rn_2$) |
| 0 | 38 | 19.5 | 9 | 175.5 | 29 | 565.5 |
| 1 | 15 | 46.0 | 9 | 414.0 | 6 | 276.0 |
| Total | 53 | -- | 18 | 589.5 | 35 | 841.5 |

H (corrected for ties): 6.010, 1 d.f., $0.02 > P > 0.01$.

It was concluded that box 2, the book-type box, yielded fewer group errors than box 1, the card-type box.

Table 18.—Group error score distribution by signs for all planned interview groups

| Error score | Number of groups ($n$) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0 | 38 | 11 | 18 | 9 |
| 1 | 15 | 6 | 4 | 5 |
| Total | 53 | 17 | 22 | 14 |

H (corrected for ties): 1.67, 2 d.f., $0.50 > P > 0.30$.

It is concluded that no evidence was provided here that one sign yields more group errors than another.

[20] Siegel, p. 312 (footnote 8).

Table 19.—Group error score distribution by blocks for all planned interview groups

| Error score | Number of groups ($n$) | Block I ($n_1$) | Block II ($n_2$) |
|---|---|---|---|
| 0 | 38 | 30 | 8 |
| 1 | 15 | 8 | 7 |
| Total | 53 | 38 | 15 |

H (corrected for ties): 3.227, 1 d.f., $0.10 > P > 0.05$.

It was concluded that block II was a suitable area for replication of the experiment on block I.

2. Analyses of group errors of planned interview groups without repeater groups:

Table 20.—Group error score distribution by boxes for planned interview groups without repeater groups

| Error score | Number of groups ($n$) | Box 1 ($n_1$) | Box 2 ($n_2$) |
|---|---|---|---|
| 0 | 30 | 8 | 22 |
| 1 | 7 | 5 | 2 |
| Total | 37 | 13 | 24 |

H (corrected for ties): 4.712, 1 d.f., $0.05 > P > 0.02$.

It was concluded that box 2 yielded fewer group errors than box 1.

Table 21.—Group error score distribution by signs for planned interview groups without repeater groups

| Error score | Number of groups ($n$) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0 | 30 | 9 | 15 | 6 |
| 1 | 7 | 5 | 1 | 1 |
| Total | 37 | 14 | 16 | 7 |

H (corrected for ties): 4.087, 2 d.f., $0.20 > P > 0.10$.

It was concluded that no evidence is provided here that one sign yielded more group errors than another.

3. Analyses of group errors of planned and special interview groups without repeater groups:

Table 22.—Group error score distribution by boxes for planned and special interview groups without repeater groups

| Error score | Number of groups (n) | Box 1 ($n_1$) | Box 2 ($n_2$) |
|---|---|---|---|
| 0 | 47 | 13 | 34 |
| 1 | 12 | 7 | 5 |
| Total | 59 | 20 | 39 |

H (corrected for ties): 2.86, 1 d.f., $0.10 > P > 0.05$.

It was concluded that no evidence was provided here that one box yielded more group errors than the other.

Table 23.—Group error score distribution by signs for planned and special interview groups without repeater groups

| Error score | Number of groups (n) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0 | 47 | 10 | 19 | 18 |
| 1 | 12 | 7 | 3 | 2 |
| Total | 59 | 17 | 22 | 20 |

H (corrected for ties): 5.28, 2 d.f., $0.10 > P > 0.05$.

It was concluded that no evidence was provided here that one sign yielded more group errors than another.

## Individual Registration Errors

Each group interviewed was given an error score on the basis of the number of individuals inaccurately registered by the group. This error score was determined by dividing the number of individuals inaccurately registered by the total number of individuals in the group. (Inaccuracies caused by failure of a group to register were counted on the same basis as inaccurate numbers reported by registered groups). Therefore, each group's error score was independent of other groups, and a correction was automatically made for the varying numbers of individuals in groups. Groups were ranked according to error scores, and comparisons between boxes, signs, and blocks were made using the Kruskal-Wallis test.

1. Analyses of individual errors of all planned interview groups:

Table 24.—Individual error score distribution by boxes for all planned interview groups

| Error score | Number of groups (n) | Box 1 ($n_1$) | Box 2 ($n_2$) |
|---|---|---|---|
| 0.00 | 34 | 8 | 26 |
| .25 | 1 | 0 | 1 |
| .50 | 1 | 0 | 1 |
| 1.00 | 17 | 10 | 7 |
| Total | 53 | 18 | 35 |

H (corrected for ties): 5.375, 1 d.f., $0.05 > P > 0.02$.

It was concluded that the occurrence of individual errors was significantly greater for box 1 than box 2.

Table 25.—Individual error score distribution by signs for all planned interview groups

| Error score | Number of groups (n) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0.00 | 34 | 8 | 17 | 9 |
| .25 | 1 | 1 | 0 | 0 |
| .50 | 1 | 0 | 1 | 0 |
| 1.00 | 17 | 8 | 4 | 5 |
| Total | 53 | 17 | 22 | 14 |

H (corrected for ties): 3.74, 2 d.f., $0.20 > P > 0.10$.

It was concluded that no one sign yielded significantly greater registration errors than another sign.

Table 26.—Individual error score distribution by blocks for all planned interview groups

| Error score | Number of groups (n) | Block I ($n_1$) | Block II ($n_2$) |
|---|---|---|---|
| 0.00 | 34 | 26 | 8 |
| .25 | 1 | 1 | 0 |
| .50 | 1 | 1 | 0 |
| 1.00 | 17 | 10 | 7 |
| Total | 53 | 38 | 15 |

H (correction for ties unnecessary): 0.94, 1 d.f., $0.50 > P > 0.30$.

It was concluded that block I did not yield significantly more individual errors than block II.

2. Analyses of individual errors of planned interview groups without repeater groups:

Table 27.—Individual error score distribution by boxes for planned interview groups without repeaters

| Error score | Number of groups (n) | Box 1 ($n_1$) | Box 2 ($n_2$) |
|---|---|---|---|
| 0.00 | 26 | 7 | 19 |
| .25 | 1 | 0 | 1 |
| .50 | 1 | 0 | 1 |
| 1.00 | 9 | 6 | 3 |
| Total | 37 | 13 | 24 |

H (corrected for ties): 3.16, 1 d.f., $0.10 > P > 0.05$.

It was concluded that the occurrence of individual errors was not significantly greater for box 1 than for box 2.

Table 28.—Individual error score distribution by signs for planned interview groups without repeaters

| Error score | Number of groups (n) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0.00 | 26 | 6 | 14 | 6 |
| .25 | 1 | 1 | 0 | 0 |
| .50 | 1 | 0 | 1 | 0 |
| 1.00 | 9 | 7 | 1 | 1 |
| Total | 37 | 14 | 16 | 7 |

H (corrected for ties): 8.099, 2 d.f., $0.02 > P > 0.01$.

It was concluded that different signs yielded significantly different numbers of individual errors.

Signs were compared in pairs. The results were as follows:

Sign 1, sign 2 —

H (correction for ties unnecessary): 4.74, 1 d.f., $0.05 > P$.

It was concluded that sign 1 yielded significantly more individual errors than sign 2.

Sign 2, sign 3 —

H: −0.02, 1 d.f., $P = 1.0$.

It was concluded that sign 2 did not yield a significantly different number of individual errors than sign 3.

Sign 1, sign 3 —

H (corrected for ties): 3.30, 1 d.f., $0.10 > P > 0.05$.

It was concluded that sign 1 did not yield a significantly greater number of individual errors than sign 3.

A conflict in conclusions is apparent. The overall analysis indicated a real difference between signs. But the paired comparisons left some doubt about the relative differences between signs. However, the weight of the evidence indicates that sign 1 yielded more individual errors than sign 2 or sign 3. And there is clearly no evidence of a real difference in occurrence of individual errors on sign 2 versus sign 3.

3. Analyses of special errors of planned and special interview groups without repeater groups:

Table 29.—Individual error score distribution by boxes for planned and special interview groups without repeater groups

| Error score | Number of groups (n) | Box 1 ($n_1$) | Box 2 ($n_2$) |
|---|---|---|---|
| 0.00 | 40 | 12 | 28 |
| .25 | 1 | 0 | 1 |
| .50 | 1 | 0 | 1 |
| .67 | 1 | 0 | 1 |
| 1.00 | 16 | 8 | 8 |
| Total | 59 | 20 | 39 |

H (correction for ties unnecessary): 0.34, 1 d.f., $0.70 > P > 0.50$.

It was concluded that one box did not yield a significantly greater number of individual errors than the other box.

Table 30.—Individual error score distribution by signs for planned and special interview groups without repeater groups

| Error score | Number of groups (n) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0.00 | 40 | 7 | 17 | 16 |
| .25 | 1 | 1 | 0 | 0 |
| .50 | 1 | 0 | 1 | 0 |
| .67 | 1 | 0 | 0 | 1 |
| 1.00 | 16 | 9 | 4 | 3 |
| Total | 59 | 17 | 22 | 20 |

H (corrected for ties): 7.21, 2 d.f., $0.05 > P > 0.02$.

It was concluded that different signs yielded a significantly different number of individual errors. From inspection of the error score distribution it is apparent that sign 1 yielded a greater number of individual errors than either sign 2 or sign 3. The difference between sign 2 and sign 3 would not be significant.

## Name-and-Address Errors

Name-and-address error scores were assigned to groups on the basis of the number of name-and-address errors contributed to the registration data by each group. The assigned error scores were ranked and the comparisons between errors on boxes, signs, and blocks were made with the Kruskal-Wallis test.

1. Analyses of name-and-address errors of all planned interview groups:

Table 31.—Name-and-address error score distribution by boxes for all planned interview groups

| Error score | Number of groups (n) | Box 1 ($n_1$) | Box 2 ($n_2$) |
|---|---|---|---|
| 0 | 36 | 8 | 28 |
| 1 | 16 | 10 | 6 |
| 2 | 1 | 0 | 1 |
| Total | 53 | 18 | 35 |

H (correction for ties unnecessary): 4.00, 1 d.f., $0.05 > P$.

It was concluded that box 1 yielded a significantly greater number of name-and-address errors than box 2.

Table 32.—Name-and-address error score distribution by signs for all planned interview groups

| Error score | Number of groups (n) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0 | 36 | 9 | 18 | 9 |
| 1 | 16 | 7 | 4 | 5 |
| 2 | 1 | 1 | 0 | 0 |
| Total | 53 | 17 | 22 | 14 |

H (corrected for ties): 3.93, 2 d.f., $0.20 > P > 0.10$.

It was concluded that there was no significant difference in the number of name-and-address errors occurring on different signs.

Table 33.—Name-and-address error score distribution by blocks for all planned interview groups.

| Error score | Number of groups (n) | Block I ($n_1$) | Block II ($n_2$) |
|---|---|---|---|
| 0 | 36 | 29 | 7 |
| 1 | 16 | 8 | 8 |
| 2 | 1 | 1 | 0 |
| Total | 53 | 38 | 15 |

H (corrected for ties): 3.78, 1 d.f., $0.10 > P > 0.05$.

It was concluded that the number of name-and-address errors occurring on block I was not significantly different from that occurring on block 2.

2. Analyses of name-and-address errors of planned interview groups without repeater groups:

Table 34.—Name-and-address error score distribution by boxes for planned interview groups without repeater groups

| Error score | Number of groups (n) | Box 1 ($n_1$) | Box 2 ($n_2$) |
|---|---|---|---|
| 0 | 28 | 7 | 21 |
| 1 | 8 | 6 | 2 |
| 2 | 1 | 0 | 1 |
| Total | 37 | 13 | 24 |

H (corrected for ties): 4.33, 1 d.f., $0.05 > P > 0.02$.

It was concluded that box 1 yielded a significantly greater number of name-and-address errors than box 2.

Table 35.—Name-and-address error score distribution by signs for planned interview groups without repeater groups

| Error score | Number of groups (n) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0 | 28 | 7 | 15 | 6 |
| 1 | 8 | 6 | 1 | 1 |
| 2 | 1 | 1 | 0 | 0 |
| Total | 37 | 14 | 16 | 7 |

H (corrected for ties): 8.06, 2 d.f., $0.02 > P > 0.01$.

It was concluded that the difference in number of name-and-address errors occurring on different signs was significant. Sign 1 obviously yielded more name-and-address errors than sign 2.

Paired comparisons were made between signs as follows:

Sign 1, sign 3—

H (corrected for ties): 2.46, 1 d.f., $0.20 > P > 0.10$.

It was concluded that sign 1 did not yield a significantly different number of name-and-address errors than sign 3.

Sign 2, sign 3—

H (correction for ties unnecessary): -0.06, 1 d.f., $P = 1.0$.

It was concluded that sign 2 did not yield a significantly different number of name-and-address errors than sign 3. A conflict in conclusions is again apparent. The overall analysis indicated a real difference between signs. But the paired comparisons left some doubt about the relative differences between signs. However, the weight of the evidence indicates that sign 1 yielded more name-and-address errors than sign 2 or sign 3, and there is clearly no evidence of a real difference in occurrence of name-and-address errors for sign 2 versus sign 3.

3. Analyses of name-and-address errors of planned and special interview groups without repeater groups:

Table 36.—Name-and-address error score distribution by boxes for planned and special interview groups without repeater groups

| Error score | Number of groups (n) | Box 1 ($n_1$) | Box 2 ($n_2$) |
|---|---|---|---|
| 0 | 42 | 12 | 30 |
| 1 | 16 | 8 | 8 |
| 2 | 1 | 0 | 1 |
| Total | 59 | 20 | 39 |

H (correction for ties unnecessary): 0.46, 1 d.f., $P = 0.50$.

It was concluded that box 1 did not yield a significantly different number of name-and-address errors than box 2.

Table 37.—Name-and-address error score distribution by signs for planned and special interview groups without repeater groups

| Error score | Number of groups (n) | Sign 1 ($n_1$) | Sign 2 ($n_2$) | Sign 3 ($n_3$) |
|---|---|---|---|---|
| 0 | 42 | 8 | 19 | 15 |
| 1 | 16 | 8 | 3 | 5 |
| 2 | 1 | 1 | 0 | 0 |
| Total | 59 | 17 | 22 | 20 |

H (corrected for ties): 6.38, 2 d.f., $0.05 > P > 0.02$.

It was concluded that the differences in occurrence of name-and-address errors between signs were significant. It is apparent from inspections that sign 1 yielded a greater number of name-and-address errors than sign 2 or sign 3. The difference between sign 2 and sign 3 would not be significant.



GPO 987-528

Wenger, Wiley D., Jr.

1964. A test of unmanned registration stations on wilderness trails: factors influencing effectiveness. U.S. Forest Serv. Res. Paper PNW-16, 48 pp., illus.

Unmanned registration stations, properly used, are effective in obtaining wilderness recreational-use information. In an intensive 2-year test of stations, the average registration rate was between 70 and 85 percent. The report evaluates and discusses effective design, location, and prescribed system for use of stations on wilderness trails. It seems that stations may yield more meaningful data at less cost than other unmanned devices.

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